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THE COST OF CLEAN WATER, VOLUME II. DETAILED ANALYSES

Federal Water Pollution Control Administration
Washington, D.C.

10 January 1968

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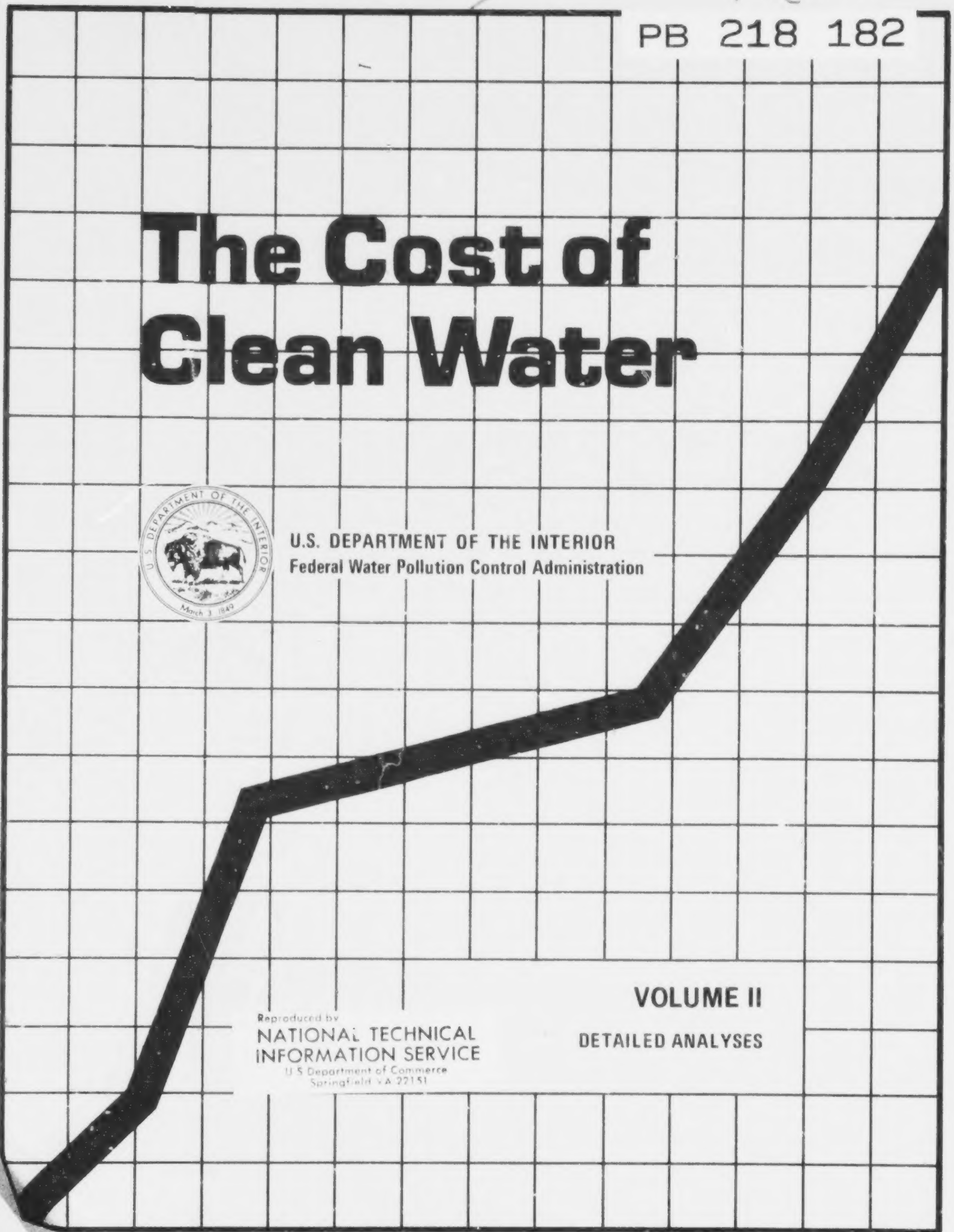

The Cost of Clean Water

March 3, 1849

U.S. DEPARTMENT OF THE INTERIOR
Federal Water Pollution Control Administration

VOLUME II

DETAILED ANALYSES

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Volume IV	State and Major River Basin Municipal Tables

THE COST OF CLEAN WATER

Volume II

Detailed Analyses

March 3, 1849

U. S. Department of the Interior
Federal Water Pollution Control Administration
January 10, 1968

I

UNITED STATES
DEPARTMENT OF THE INTERIOR
OFFICE OF THE SECRETARY
WASHINGTON, D.C. 20240

MAR 13 1968

Dear Mr. President:

This transmits Volume II of our first report to the Congress on the national requirements and costs of water pollution control.

Section 16(a) of the Federal Water Pollution Control Act, as amended, directs the Secretary of the Interior to conduct three studies - one, a study of the cost of carrying out the Federal Water Pollution Control Act, as amended; another, a study of the economic impact on affected units of government of the cost of installing waste treatment facilities; and the third, a study of which Volume II is a part, of the national requirements for and the cost of treating municipal, industrial, and other effluent to attain water quality standards established pursuant to the Act or applicable State law. These studies are required to cover the five-year period beginning July 1, 1968, and to be updated each year thereafter.

Volume I, a summary of the major findings and conclusions reached in the study, was transmitted to the Congress on January 10, 1968. Volume III, Industrial Waste Profiles, a description of the source and quantity of pollutants produced by each of ten industries, has also been transmitted.

This report (Volume II) is a detailed analysis supporting the major findings and conclusions reported in Volume I of what, in our view, is the most ambitious cost analysis on this subject yet undertaken. Volume IV, State and Major River Basin Municipal Tables will follow shortly.

As I have indicated, the attached study is one of several related studies mandated by the Congress by Section 16(a). The studies of the economic impact on affected units of government and the cost of carrying out the Act were transmitted to the Congress on March 7, 1968, in company with a study of possible methods for providing incentives designed to assist in the construction by industry of water pollution control facilities. The incentives

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study was authorized by Section 18 of the Act. Together, these studies represent a major step toward improving our understanding of the costs and related economic problems of water pollution control.

Sincerely yours,

Secretary of the Interior

Hon. Hubert H. Humphrey
President of the Senate
Washington, D. C. 20510

Enclosure

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DEPARTMENT OF THE INTERIOR
OFFICE OF THE SECRETARY
WASHINGTON, D.C. 20240

MAR 1 3 1968

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Sincerely yours,

Stew L Udall

Secretary of the Interior

Hon. John W. McCormack
Speaker of the House of
  Representatives
Washington, D. C. 20515

Enclosure

PREFACE

The Federal Water Pollution Control Act (Section 16(a)) directs the Secretary of the Interior to conduct a comprehensive analysis of the national requirements for, and the cost of, treating municipal, industrial, and other wastewater effluents to attain water quality standards established under the Act. This first analysis is required to be submitted to the Congress by January 10, 1968, to cover Fiscal Years 1969-1973, inclusive, and to be updated each year thereafter.

This study is extremely important because there are no firm estimates of the national costs of achieving satisfactory water pollution abatement levels. However, there is widespread agreement that water pollution is a significant and growing national problem that must be solved. Over the past two years, estimates of municipal requirements and the costs involved have been made by the U. S. Senate Committee on Public Works, the Conference of State Sanitary Engineers, and the Business and Defense Services Administration of the Department of Commerce. These prior estimates have been based, at least in part, on different facility requirements, more extended time projections, diverse cost criteria, and dissimilar geographical coverage. Thus, while these estimates have been informative, they have not been sufficiently comprehensive to serve as a basis for determining national requirements and cost of attaining water quality standards.

Even more varied estimates of the industrial waste treatment costs have come from still other sources. While these studies too have contributed useful information, they have not provided a generally acceptable estimate of the national costs of industrial water pollution control.

It is generally recognized that effluents other than from municipal and industrial sources also have a tremendous influence on the total problem of water pollution control, but here again no satisfactory overall estimate has been made of what it will cost to control them. Because of the great diversity of these other effluents, calculating such costs is immensely complicated.

The present study initiates what will be a continuing evaluation, aimed at estimating water pollution control costs with increasing accuracy. Although it has not been possible to arrive at a completely definitive estimate of required costs, the present study is believed to be the most comprehensive cost estimate ever developed, as well as a sound base of information upon which to build future analyses.

This is the Detailed Analyses of the national requirements and costs of water pollution control (Volume II). A summary (Volume I) of the major findings and conclusions was transmitted to the Congress on January 10, 1968. Further detailed information to support the findings and conclusions is contained in two additional volumes. Volume III (Industrial Waste Profiles) consists of 10 studies of major water-using industries which describe the costs and effectiveness of alternative methods of reducing industrial wastes. Volume IV (State and Major River Basin Municipal Tables) contains a tabular breakdown of municipal treatment works and sanitary sewer construction costs and the operation and maintenance costs of treatment works for each of the 50 States and the Nation's major river basins as described by the Water Resources Council.

Joe G. Moore, Jr.

Commissioner
Federal Water Pollution Control Administration

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MUNICIPAL REQUIREMENTS AND COST ESTIMATES

Volume II

Part I

March 3, 1849

U. S. Department of the Interior
Federal Water Pollution Control Administration
January 10, 1968

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INTRODUCTION

Part I of Volume II sets forth the requirements for, and the cost of, treating municipal waste effluents to attain water quality standards during Fiscal Years 1969-1973, by State and Water Resource Region. The five-year period projected parallels that set as a national goal for achieving compliance with water quality standards. The Part I estimates include the requirements and costs of controlling water pollution emanating from unsewered urban populations and from combined sewer overflows, since these, too, are related to the total problem. Assuming that waste treatment works construction needed to attain water quality standards occurs as projected to 1973, operation and maintenance costs will increase considerably. Estimates of these costs are also included for each State and Water Resource Region.

A number of assessments of waste treatment needs nationally have been made in recent years. They vary as to cost criteria, years projected, geographical coverage, and type of facilities considered.

A report to the Committee on Public Works, U. S. Senate, showed present and additional needs through 1972 as amounting to $3.9 billion. The population covered was approximately 48 million. The facilities included were treatment plants, interceptor sewers and, for some cities, sanitary sewers and control of combined sewer overflows.[1]

Another report by the Conference of State Sanitary Engineers estimated the cost of eliminating the backlog for waste treatment facilities as $2.6 billion. When provision is made for population growth and obsolescence, the total need is estimated by CSSE to require an average annual expenditure of $961 million through 1972 or $6.7 billion over the seven-year period (1966-1972).[2]

A third study provides historical data of construction put in place in actual dollars from 1955 through 1966, and a projection of requirements from 1967 through 1980, in constant 1966 dollars. This report estimates that an expenditure of $3.7 billion will be needed by 1980 to eliminate the deficiencies in waste treatment facilities. Further, it estimates that the total volume of construction needed to offset obsolescence and depreciation for the

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[1] *"Sewage Treatment Needs of the 100 Largest Cities in the United States - Present Needs and Future Needs Through 1972," Steps Toward Clean Water, Report to the Committee on Public Works, United States Senate, January 1966, p. 20.*

[2] *"Sixth Annual Survey of Municipal Waste Treatment," Conference of State Sanitary Engineers, January 1, 1966, p. 1.*

14-year period would amount to approximately $4.3 billion. Population growth during the period would require the expenditure of an additional $6.4 billion. This is an estimated expenditure of $14.4 billion for wastewater utilities by 1980. These cost estimates are for treatment plants only and do not include the cost of interceptor sewers.[3]

This report has estimated the costs of providing waste treatment to the total urban population of the U. S. by 1973 (162.6 million) at appropriate treatment levels to comply with water quality standards. In order to meet the standards by 1973, it is estimated that 90% of the urban population will require secondary treatment facilities and 10% primary treatment facilities. The urban population in 1973 will be 75% of the total U. S. population. Currently, only 55% of the urban population is served by adequate waste treatment facilities.

This study of the national municipal sewage treatment plant requirements is based on the 1962 Inventory of Municipal Waste Treatment Facilities,[4] updated to January 1, 1967, by reference to the FWPCA records of Federal grants for sewage treatment works. An estimated 60% (by total dollar value) of municipal sewage treatment works construction from 1962 to 1967, received Federal grants. Large metropolitan treatment works constructed without Federal funds were also included. This procedure was employed in lieu of a completely new Inventory which would have required extensive work by the State water pollution control agencies at a time when they were under prior heavy demands to develop water quality standards for interstate waters.

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[3] "Regional Construction Requirements For Water and Wastewater Facilities, 1955 - 1967 - 1980," U. S. Department of Commerce, Business and Defense Services Administration, October 1967.

[4] Glass, Andrew C. and Kenneth H. Jenkins, Statistical Summary of 1962 Inventory Municipal Waste Facilities in the United States, prepared by the Division of Water Supply and Pollution Control, U. S. Department of Health, Education and Welfare, Public Health Service, U. S. Government Printing Office, Washington, D. C., 1964.

ASSUMPTIONS OF THE STUDY

It was necessary to make a number of assumptions and to develop a methodology to assess the State and Water Resource Region needs for and costs of municipal waste treatment. The assumptions and the reasons therefore, are explained as follows:

(1) Adequate treatment to attain water quality standards is required for the total urban population of the United States. The total waste treatment service provided to the U. S. population as shown in the 1962 Inventory of Municipal Waste Treatment Facilities (the latest complete inventory) and the needs in facilities construction for untreated wastes reported by the 1962 Annual Survey of Municipal Waste Treatment Needs closely approximate the total urban population in that year.

The Bureau of the Census defines urbanized areas in part as, "... incorporated places with 2,500 inhabitants or more, incorporated places with less than 2,500 inhabitants, provided each has a closely settled area of 100 dwelling units or more, unincorporated territory with a population density of 1,000 inhabitants or more per square mile..."[5] An unincorporated community with a population density of less than 1,000 inhabitants per square acre would normally be unable to finance a community waste treatment works unless it became a part of a special district. Incorporated places of less than 100 dwelling units would not generally exceed a population of approximately 400 persons based on the Census average of 3.3 persons per dwelling unit. Such communities would tend not to have the financing capability to construct a waste treatment works. Therefore, non-urban or rural communities are not considered for the purposes of this study to have significant requirements in terms of overall cost requirements.

This study has estimated urban population in the U. S. in 1968 as 146 million, with the total U. S. population amounting to 200 million. The 54 million persons residing in rural areas were considered as administratively or economically incapable of constructing waste treatment works solely within their own community for purposes of these estimates.

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[5] *"United States Summary - Number of Inhabitants," U. S. Census of Population: 1960, U. S. Department of Commerce, Bureau of the Census, U. S. Government Printing Office, Washington, D. C., 1961.*

(2) Adequate treatment is defined as at least secondary type of waste treatment, except for those areas where primary waste treatment has been or is likely to be approved as conforming to water quality standards.

To estimate the costs of carrying out waste treatment requirements embodied in standards still being negotiated, it was necessary to assume a given level of treatment as generally representative of that contained in the standards. It was assumed that a conventional secondary treatment level (at least 85% effective removal of five-day biochemical oxygen demand for domestic sewage) would prevail for treating municipal wastes with some exceptions as described later. This conforms with the policy reflected in the Federal Water Pollution Control Administration's "Guidelines for Establishing WATER QUALITY STANDARDS for Interstate Waters" issued in May 1966. Guideline No. 8 reads:

> No standard will be approved which allows any wastes amenable to treatment or control to be discharged into any interstate water without treatment or control regardless of the water quality criteria and water use or uses adopted. Further, no standard will be approved which does not require all wastes, prior to discharge into any interstate water, to receive the best practicable treatment or control unless it can be demonstrated that a lesser degree of treatment or control will provide for water quality enhancement commensurate with proposed present and future water uses.

Lending validity to this assumption was the provision in all the 10 states whose standards were approved as of December 1, 1967, for secondary treatment for all discharges to fresh water. Nevertheless, the basic assumption of secondary treatment of municipal wastes was made in full recognition that in some states primary treatment may be adequate and in others secondary treatment may be inadequate during the period FY 1969-1973.

Cost estimates presented here are adjusted to reflect standards and plans currently under review which may reasonably be expected to require less than secondary treatment for certain major municipalities during the FY 1969-1973 period and which, accordingly, lowered cost requirements significantly.

Some areas may find it necessary to provide treatment exceeding or supplementing the secondary level. For example, treatment for phosphate removal may be required at some facilities in the Lake Erie sub-basin and in New Jersey tertiary waste treatment of municipal effluent may be required where shellfish contamination has occurred. In New Jersey, this could take the form of treatment by stabilization ponds after secondary treatment or possibly advanced waste treatment. However, it has not been possible, at this time, to estimate the cost increases which would attend such treatment.

(3) Municipal waste treatment essential for the standards will be attained nationally by the end of FY 1973.
Table I-1 shows the cost of projected needs phased proportionately over the five-year period, FY 1969-1973. This is consistent with implementation plans of most state standards approved or approaching approval. The procedure is also useful to illustrate annual increments, to estimate annual depreciation and annual construction cost increases, and to obtain associated operation and maintenance cost estimates. It is recognized that, as a practical matter, achievement of the 1969-1973 goals will not occur at a fixed rate. There are lags from the time Federal construction grants are approved until construction is actually in place and financing the estimated level of construction may present difficulties.

TABLE I-1

U. S. POPULATION AND INDUSTRY SERVED BY EXISTING MUNICIPAL FACILITIES AND ESTIMATED ANNUAL REQUIREMENTS AND C'ITAL OUTLAYS, FISCAL YEARS 1969-1973

Municipal Service	1968	Projected Years					Total 1969-1973
		1969	1970	1971	1972	1973	
Adequate treatment demand by:							
Urban population of U. S. (thousands)	145,602	148,661	151,640	155,252	158,893	162,555	
Industrial discharge to public sewers (bil. gal.)	1,338.5	1,386.3	1,437.0	1,490.3	1,550.1	1,612.2	
Summary of need for adequate treatment:							
Urban population, total (thousands)	145,602[1]						
With adequate treatment	81,703						
Less than adequate treatment	31,865						
No treatment	32,293						
Projected needs, total (thousands)		16,222	16,222	16,222	16,222	16,222	81,110
Upgrading of treatment		6,373	6,373	6,373	6,373	6,373	31,865
Constructing facilities for untreated wastes		6,459	6,459	6,459	6,459	6,459	32,293
Increases in urban population		3,390	3,390	3,390	3,390	3,390	16,950
Industrial discharge to public sewers, total (bil. gal.)	1,338.5						
With adequate municipal treatment	826.2						
Less than adequate municipal treatment	512.3						
Projected needs, total (bil. gal.)		150.3	153.2	155.8	162.3	164.6	786.0
Upgrading of treatment		102.5	102.5	102.5	102.5	102.5	512.3
Increases to public sewers		47.8	50.7	53.3	59.8	62.1	273.7
Investment and capital outlays needed (mil. dol.):							
Investment in place, total (mil. dol.)	$5,714.8	$7,066.5	$8,418.2	$9,769.9	$11,121.6	$12,473.3	
Adequate treatment	4,148.2	5,813.2	7,478.2	9,143.2	10,808.2	12,473.3	
Less than adequate treatment	1,566.6	1,253.3	940.0	626.7	313.4		
Capital outlays needed, total (mil. dol.)		1,517.7	1,558.2	1,598.8	1,639.4	1,679.9	$7,994.0
Upgrading less than adequate facilities		373.7	373.7	373.7	373.7	373.7	1,868.5
Constructing facilities for untreated wastes		541.5	541.5	541.5	541.5	541.5	2,707.5
Increases, population and industry[2]		436.5	436.5	436.5	436.5	436.5	2,182.5
Allowances for depreciation		166.0	206.5	247.1	287.7	328.2	1,235.5

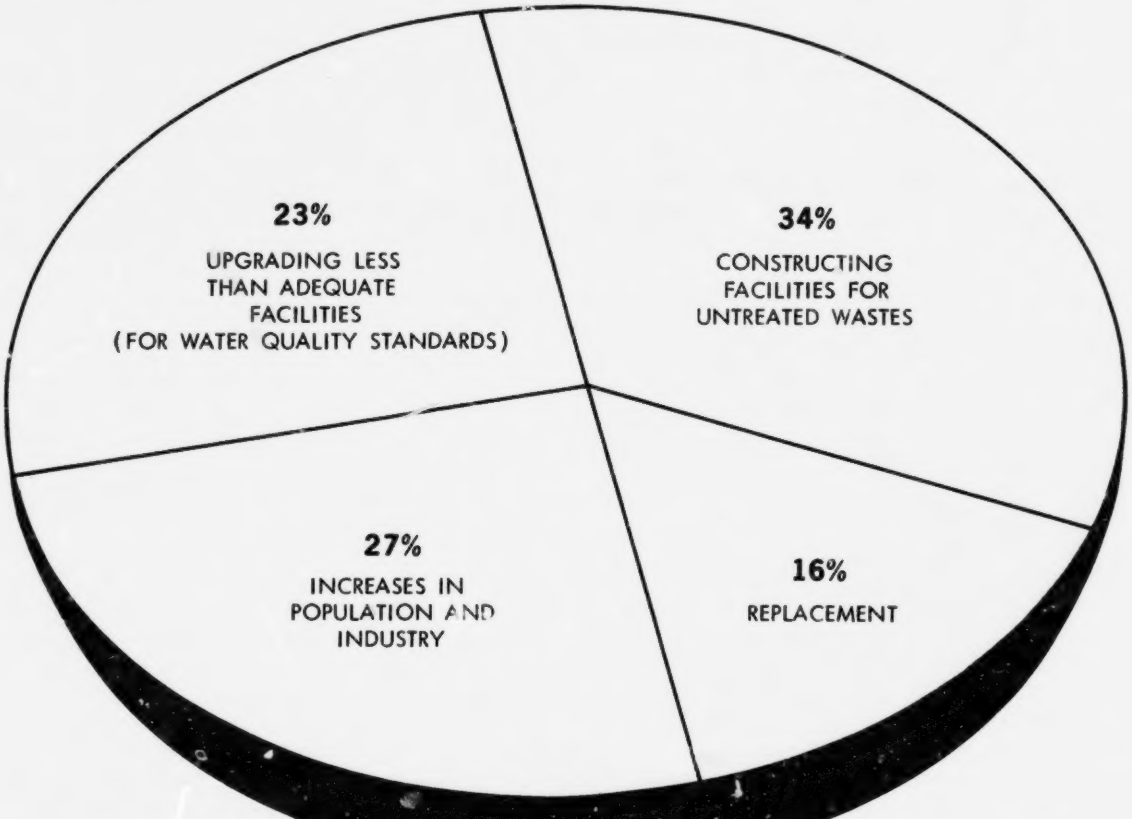
[1] *Subtotals exceed the total by 259,000 persons located in several states where the population served by treatment works exceeds the urban population.*

[2] *Includes construction costs for additional capacity for five years of population growth in each state beyond the 1969-1973 period of the cost estimate of needs.*

Note: *The cost of municipal waste treatment construction works was phased proportionately over the five-year period to illustrate possible annual increments and to serve as a basis for estimating annual depreciation and increases in construction costs. This procedure was also useful for arriving at estimates of associated operation and maintenance costs.*

Source: *Based on 1962 Inventory of Municipal Waste Facilities, updated; Census of Population, 1960; Bureau of Census Population Estimates, Series P-25; 1963 Census of Manufactures, "Water Use in Manufacturing"; FWPCA Construction Grant records.*

FIGURE I - 1
FIVE YEAR CAPITAL OUTLAYS REQUIRED TO OBTAIN ADEQUATE MUNICIPAL WASTE TREATMENT FOR THE U.S. URBAN POPULATION (1969-1973)



TOTAL $8.0 BILLION

COST METHODOLOGY

Estimates of construction costs are based on total costs eligible for Federal grants assistance. These are costs incurred in new sewage treatment works construction or additions, extensions, alterations, acquisitions, and improvements to, by, or of existing treatment works; costs for necessary intercepting sewers, outfall sewers, pumping, power, and other equipment; costs for preliminary planning and such other actions necessary to sewage treatment construction such as engineering, legal and fiscal investigations, studies and designs, including the supervision and inspection of construction.

Costs may be incurred in waste treatment construction which are ineligible for inclusion in the total project cost upon which Federal aid is based. Such costs may pose a considerable burden upon the community, particularly in large metropolitan areas where land is costly. Items ineligible for FWPCA construction grants include land acquisition (for treatment plant site), sewage collection systems or any part thereof (intercepting and outfall sewers are not considered to be part of the collection system), and any work not included in the project as approved by the Department of the Interior.

When it is not possible to isolate treatment works from homes and businesses, the project cost is increased by the need to landscape, beautify, and even condemn or relocate public and private structures. New streets, viaducts and acquisition of rights-of-way add to the ineligible costs. The extent of such landscaping, beautification and relocation by a community depends upon its financial capability, esthetic needs, and opportunities to shift or delay attendant costs.

In this study, municipal waste treatment capital costs are based upon per capita costs for activated sludge-type plants. The costs of trickling filter treatment works constructed under the PL-660 program approximate those for activated sludge construction. Another secondary type of waste treatment, stabilization ponds, has much lower construction costs. However, in terms of percentage of population served, only a few states show significant trends toward stabilization ponds. The per capita costs used to calculate total costs of providing waste treatment service are based upon design and cost information for treatment works constructed under the PL-660 Federal construction grants program (Table I-2). Projects representing all sections of the Nation are included.

Since a mean of the per capita costs of all projects was used to calculate total costs of needed treatment works, the costs for sections of the Nation may be over or underestimated. For example, there are indications that treatment works projects in the northeast have higher estimated per capita costs than those of some other regions. The FWPCA Northeast Regional Office has submitted some State estimates (New York, New Hampshire, Vermont and Maine)

TABLE I-2

SEWAGE TREATMENT WORKS CONSTRUCTION PER CAPITA COSTS[1] (TOTAL PLANT, INTERCEPTORS AND OUTFALLS)

(1968 dollars)

Design Population	Primary Types of Treatment	Secondary Types of Treatment	
		Activated Sludge	Stabilization Ponds[2]
0 - 999	$148	$175	$85
1,000 - 4,999	96	117	57
5,000 - 9,999	68	86	29
10,000 - 24,999	54	69	14
25,000 - 49,999	43	56	
50,000 - 99,999	35	45	
100,000 and up	30	40	

---

[1] *Does not include land costs.*

[2] *Uniform cost States: North Carolina, South Carolina, Georgia, Alabama, Kansas, Washington.*

Source: Based upon the design and actual cost information of sewage treatment projects constructed under PL 84-660.

that are two to three times the estimates developed by the Cost Estimate Study here reported.

Future annual Cost Estimate Studies must evaluate these differences. The higher costs may be attributable to several factors - inclusion of ineligible costs, joint municipal-industrial projects in which the industrial discharges predominate, projects planned primarily for storm water overflow, or projects which include trunk and collecting sewers, thus exceeding the typical treatment plant-interceptor cost ratio of approximately 55% to 45%.

Sewage treatment plants are normally designed for sufficient capacity to accommodate additional quantities of sewage resulting from population and industrial growth. According to Fair and Geyer[6] many factors are considered in deciding upon a period of design. Among these factors are obsolescence and depreciation, influence of a location upon plant expansion, anticipated growth rate of population and industry, interest rate to be paid on bonded indebtedness, future construction cost changes, and the performance of the works during early years when operated below capacity. Water quality standards compliance will be a major consideration in future sewage treatment plant designs. Fair and Geyer have noted that when growth and interest rates are high, the design periods for treatment works may amount to 10-15 years. Because of the many variables involved in arriving at average excess treatment plant capacity included in plant designs and the unavailability of current excess capacity data, this analysis is based conservatively on a minimum plant design period for growth of five years and a maximum of 10 years. Therefore, projected construction of waste treatment plants in the period 1969-1973 would be assumed to include the cost of additional capacity for population growth estimated to occur by 1978 or an average of 7-1/2 years excess capacity for population growth.

The cost of upgrading primary treatment plants to secondary treatment was determined by applying per capita costs for upgrading to the population served by present primary waste treatment plants in each State. The per capita costs were derived from actual costs for such projects contained in Federal construction grant records correlated with design populations.

The cost of constructing facilities for untreated wastes was obtained by projecting the urban population of each State to 1968 by population size range. The total population served by primary and secondary treatment works, in each population size range, in each State, was compared to the total projected urban population in each size range. The population difference was considered as lacking any type of waste treatment, and the need defined accordingly.

---

[6] *Fair, Gordon M. and John C. Geyer, Water Supply and Wastewater Disposal John Wiley & Sons, Inc., New York, New York, April 1963.*

This population was classified according to size range for the purpose of applying appropriate per capita costs of constructing secondary waste treatment works. These costs in 1968 were totaled for each State. The per capita costs of constructing secondary waste treatment works were derived from actual costs of such projects contained in Federal construction grant records correlated with design populations.

The cost of providing secondary waste treatment works for urban population growth and increase in industrial discharges to public sewers was obtained by projecting urban population growth in each State by population size range from 1968 to 1973. Per capita costs of constructing secondary waste treatment works for each population size range were applied to the projected populations and total cost was computed for each State.

Allowances for depreciation were obtained by using an estimated annual depreciation rate of 3% of accumulated invested capital. The assumption is that waste treatment plants have an average effective life of 25 years and interceptor and outfall sewers, 50 years. Annual replacement needs then would be 4% for the plants and 2% for the interceptor and outfall sewers. Therefore, an average annual rate of 3% was used for calculating depreciation based on the total cost of waste treatment works averaging 55% plant and 45% interceptors and outfalls, according to Federal construction grant records.

Because of the aggregative analytical techniques used, it was not possible to confine these cost estimates to interstate and coastal waters to which the Act applies; therefore, the cost estimates presented in this report are state-wide and national in scope.

The total costs by State and Water Resource Region are expressed in both "constant" and "current" dollars. Constant 1968 dollars were obtained by using July 1967, the beginning of FY 1968, as the base. Current dollars were obtained by multiplying the 1968 constant dollar estimates for each year of the FY 1969-1973 period by cost indexes projected for these years.

MUNICIPAL WASTE TREATMENT CONSTRUCTION COSTS FOR 1969-1973

On the basis of the assumptions and methodology described, waste treatment works construction to attain water quality standards in the five-year period, 1969-1973, will require the expenditure of an estimated $8.0 billion in constant 1968 dollars. Increasing construction costs during the period could expand the total national cost to $8.7 billion. It is estimated that sewage treatment plant construction costs will increase about 3.3% annually during this period.

The urban population of the U. S. is estimated as 146 million in FY 1968, increasing to approximately 163 million by 1973 and 188 million by 1978. Thus, 17 million more people will become urban area residents within these next five years and an additional 25 million by 1978. If these increases follow the same pattern of urbanization, by size of community, that took place in the decade, 1950-1960, capital outlays of about $2.2 billion will be needed for adequate waste treatment facilities in the period 1969-1973. These outlays would provide additional capacity for population growth expected to occur by 1978. (Tables I-3 and I-4.)

Primary facilities serve 43 million persons or 30% of the Nation's 1968 urban population. Facilities serving 32 million of this population must be upgraded to secondary waste treatment. Such upgrading will require, in the five-year period, approximately $1.9 billion. (Tables I-3 and I-4.)

Adequate waste treatment facilities will need to be constructed to serve the country's 32 million urban area residents that at present have no waste treatment facilities. Providing adequate treatment facilities for these 32 million persons in the 1969-1973 period will require capital outlays of about $2.7 billion. (Tables I-3 and I-4.)

Depreciation of plant and equipment is a continuing expense. During this five years, it will amount to $1.2 billion, assuming the schedule of construction for providing for urban population increases, upgrading of facilities and construction of facilities for untreated wastes is systematically followed in the five-year period. (Table I-3.)

In summary, to provide for population growth, upgrade primary treatment works, construct works for urban populations presently unserved, and replace depreciated plant and equipment, will cost an estimated $8.0 billion during the period 1969-1973. Construction cost increases could raise this estimate to $8.7 billion.

The 10 highest ranking States in capital outlay required to attain adequate waste treatment by 1973 are, in order: New York - $963.6 million, California - $645.2 million, Michigan - $535.8 million, New Jersey - $505.0 million,

TABLE I-3A

CAPITAL OUTLAYS NEEDED TO OBTAIN ADEQUATE MUNICIPAL WASTE TREATMENT FOR THE U. S. URBAN POPULATION, 1969-1973

($ Millions)

State	Total (Current Dollars)	Total (Constant Dollars)	Upgrading of Facilities	Constructing Facilities For Untreated Wastes	Increases In Urban Population[1]	Allowances For Depreciation
United States	$8,693.1	$7,994.0	$1,868.7	$2,707.4	$2,182.5	$1,235.4
Alabama	137.0	131.0	33.0	39.0	42.0	17.0
Alaska[2]	14.5	12.8		7.0	5.0	.8
Arizona	90.0	84.0	4.0	25.5	44.0	10.5
Arkansas	48.5	45.5	12.0	4.5	20.0	9.0
California[2]	732.2	645.2	2.0	370.5	150.5	122.2
Colorado	103.6	97.6	26.0	18.0	40.5	13.1
Connecticut	188.3	175.8	69.5	50.0	36.5	19.8
Delaware	31.5	30.1	13.0	4.5	9.5	3.1
District of Columbia[3]	23.0	21.4			8.0	13.4
Florida[2]	369.6	347.0	46.0	191.5	68.0	41.5
Georgia	223.1	209.6	53.5	60.5	69.0	26.6
Hawaii[2]	40.1	35.5		27.5	4.5	3.5
Idaho	24.5	23.0	10.5	2.5	6.5	3.5
Illinois	399.4	367.0	48.0	102.0	136.0	81.0
Indiana	176.1	162.1	39.5	45.5	45.0	32.1
Iowa[2]	36.0	34.7			15.5	19.2
Kansas	52.5	49.6	14.5	.5	22.5	12.1
Kentucky	130.0	120.8	39.0	24.5	40.5	16.8
Louisiana	195.0	182.1	21.0	80.5	63.0	17.6
Maine	47.0	43.9	6.0	31.5	3.0	3.4
Maryland	136.1	128.4	11.0	45.5	53.0	18.9
Massachusetts[2]	200.0	186.3	64.0	78.5	10.0	33.8
Michigan	592.6	535.8	223.0	144.5	103.5	64.8
Minnesota	186.0	172.4	64.5	32.5	49.5	25.9
Mississippi	57.0	54.1	3.0	24.0	22.0	5.1
Missouri[2]	137.6	126.8	13.0	45.4	50.5	17.9
Montana	27.0	25.5	16.0		6.0	3.5
Nebraska[2]	30.5	29.0	9.9		11.5	7.6
Nevada	19.5	18.1	1.0	.5	13.0	3.6
New Hampshire	35.0	32.6	7.5	16.0	6.0	3.1
New Jersey	561.1	505.0	167.0	161.0	113.5	63.5
New Mexico	40.5	37.6	1.0	5.5	23.5	7.6
New York	1,070.2	963.6	266.0	390.5	204.0	103.1
North Carolina	101.5	95.6	16.0	22.5	36.0	21.1
North Dakota	13.0	11.3	2.5	4.0	2.5	2.3
Ohio	500.7	461.7	122.0	134.5	131.5	73.7
Oklahoma	60.5	57.4	10.5	6.0	25.5	15.4
Oregon	145.3	130.2	29.5	41.5	44.0	15.2
Pennsylvania	331.6	310.9	149.5	27.5	53.5	80.4
Rhode Island	41.5	38.3	9.5	17.5	5.5	5.8
South Carolina	100.0	93.9	19.0	35.5	27.0	12.4
South Dakota	14.0	12.5	5.0		4.0	3.5
Tennessee	154.6	147.8	19.5	68.0	43.5	16.8
Texas	342.5	323.6	17.0	81.0	155.5	70.1
Utah	136.0	127.4	2.0	88.0	26.0	11.4
Vermont	19.0	17.7	10.0	3.0	2.5	2.2
Virginia[3]	206.6	194.7	65.0	47.0	59.0	23.7
Washington[2]	173.3	155.3	33.0	84.5	19.0	18.8
West Virginia	55.0	50.4	25.0	13.5	5.5	6.4
Wisconsin	133.3	122.4	47.0	3.5	42.0	29.9
Wyoming[2]	9.7	9.0	2.3	.5	4.5	1.7

[1] *Includes construction costs for additional capacity for five years of population growth in each State beyond the 1969-1973 period of the cost estimate of needs.*

[2] *Water quality standards adopted call for primary waste treatment in some urban areas of State. Standards adopted for other States call for at least secondary waste treatment.*

[3] *A portion of the capital outlays shown for Virginia may actually occur in the District of Columbia with service contracted to Virginia.*

Source: Based on 1962 Inventory of Municipal Waste Treatment, updated; Census of Population, 1960; Bureau of Census Population Estimates, Series P-25.

TABLE I-3B

CAPITAL OUTLAYS NEEDED TO OBTAIN ADEQUATE MUNICIPAL WASTE TREATMENT
FOR THE U. S. URBAN POPULATION, 1969-1973 (CONT'D.)
($ Millions)

Water Resource Region[1]	Total (Current Dollars)	Total (Constant Dollars)	Upgrading of Facilities	Constructing Facilities For Untreated Wastes	Increases In Urban Population[1]	Allowances For Depreciation
United States	$8,693.1	$7,994.0	$1,868.7	$2,707.4	$2,182.5	$1,235.4
Alaska	14.5	12.8		7.0	5.0	.8
Arkansas-White-Red	229.9	216.5	41.9	39.4	92.2	43.0
California	735.2	647.8	2.6	371.3	151.4	122.5
Columbia-North Pacific	349.1	314.4	77.6	127.7	70.7	38.4
Great Basin	130.8	122.4	2.3	79.4	28.9	11.8
Great Lakes	1,164.3	1,059.2	376.3	285.7	246.0	151.2
Hawaii	40.1	35.5		27.5	4.5	3.5
Lower Colorado	108.0	100.8	4.7	29.5	53.3	13.3
Lower Mississippi	232.9	219.1	25.4	97.7	73.7	22.3
Missouri	250.4	234.0	61.5	38.0	91.8	42.7
North Atlantic	2,611.0	2,392.2	746.6	801.6	512.1	331.9
Ohio	728.3	674.6	205.8	172.3	180.7	115.8
Rio Grande	64.7	60.5	2.6	11.9	33.4	12.6
Souris-Red-Rainy	10.2	9.0	2.5	2.6	2.2	1.7
South Atlantic-Gulf	978.6	921.9	172.5	367.7	259.3	122.4
Tennessee	62.9	60.1	8.9	25.5	18.3	7.4
Texas-Gulf	295.7	279.3	14.6	69.5	134.8	60.4
Upper Colorado	14.7	13.8	1.3	6.2	4.6	1.7
Upper Mississippi	671.8	620.1	121.6	146.9	219.6	132.0

[1] *Water Resource Regions proposed by Water Resource Council for Type I Comprehensive Surveys. Data not available to estimate capital outlays needed for the Puerto Rico-Virgin Islands Region.*

Source: Based on 1962 Inventory of Municipal Waste Treatment, updated; Census of Population; 1960 Bureau of Census Population Estimates, Series P-25.

FIGURE I-2
WATER RESOURCE REGIONS
PROPOSED BY WATER RESOURCE COUNCIL FOR TYPE I COMPREHENSIVE SURVEYS

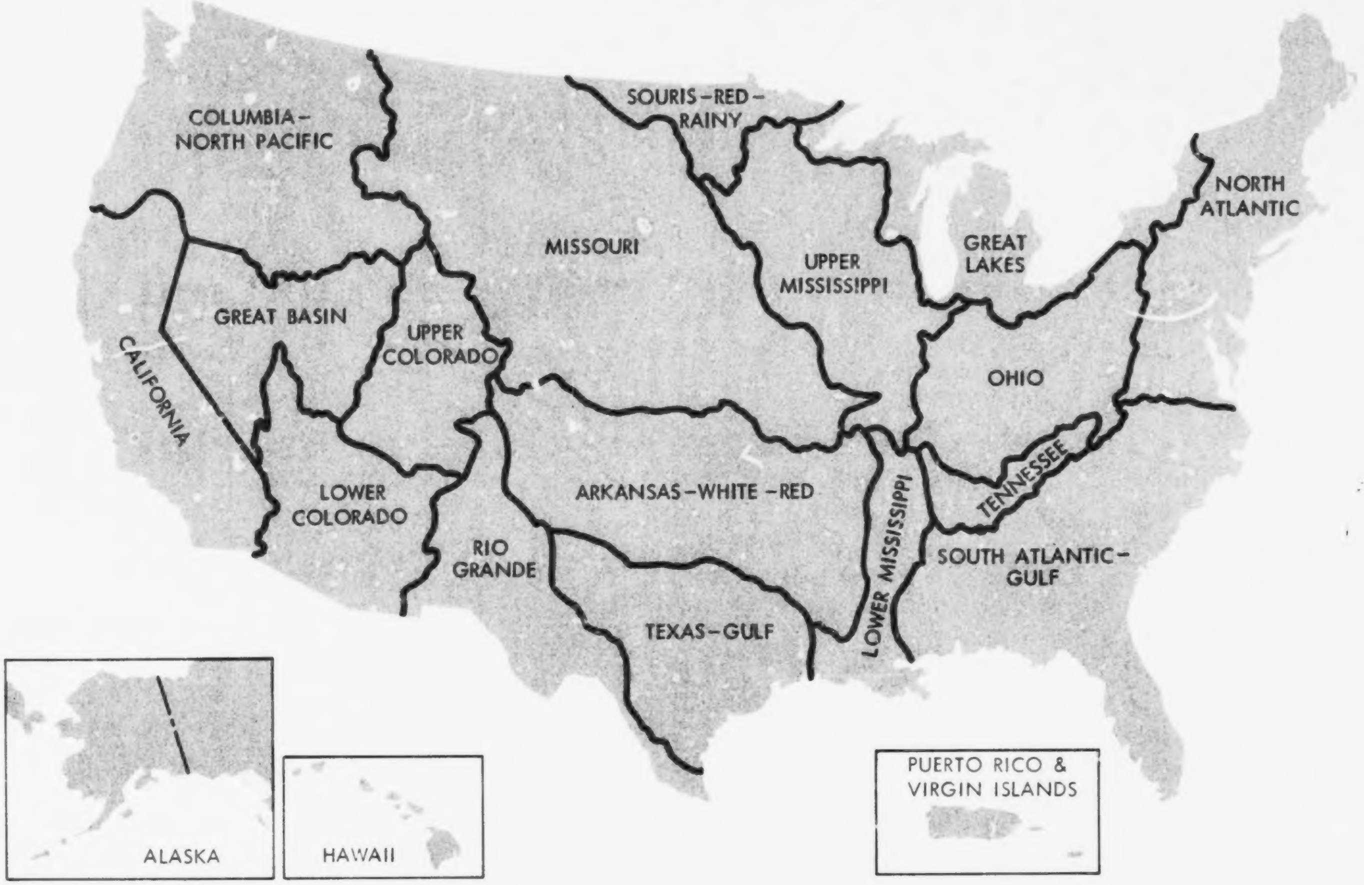

COLUMBIA-NORTH PACIFIC
SOURIS-RED-RAINY
MISSOURI
UPPER MISSISSIPPI
GREAT LAKES
NORTH ATLANTIC
GREAT BASIN
UPPER COLORADO
CALIFORNIA
OHIO
TENNESSEE
LOWER COLORADO
ARKANSAS-WHITE-RED
LOWER MISSISSIPPI
SOUTH ATLANTIC-GULF
RIO GRANDE
TEXAS-GULF
ALASKA
HAWAII
PUERTO RICO & VIRGIN ISLANDS

TABLE I-4

URBAN POPULATION SERVED BY ADEQUATE AND LESS THAN ADEQUATE MUNICIPAL WASTE TREATMENT FACILITIES AND URBAN POPULATION NOT SERVED, BY STATE: FY 1968

(In thousands, except percent)

State	Total Urban Population	Population With Adequate Treatment Facilities	Population With Less Than Adequate Treatment Facilities	Urban Population With No Treatment Facilities	Percent of Urban Population With Less Than Adequate Or No Treatment Facilities
United States[1]	145,602	81,703	31,865	32,293	44.1%
Alabama	2,140	819	678	643	61.7
Alaska[2]	121	19		102	84.2
Arizona	1,411	711	34	666	49.6
Arkansas	937	684	156	97	27.0
California[2]	17,651	12,766	36	4,849	27.7
Colorado	1,602	854	593	155	46.7
Connecticut	2,342	312	1,286	744	86.7
Delaware	356	9	267	80	97.5
District of Columbia	832	832			
Florida[2]	4,860	1,741	864	2,255	64.2
Georgia	2,727	1,081	1,003	643	60.4
Hawaii[2]	591	162		429	72.6
Idaho	349	160	134	55	54.2
Illinois	8,923	7,410	586	927	17.0
Indiana	3,182	2,286	529	367	28.2
Iowa[1] [2]	1,526	1,590			
Kansas[2]	1,475	1,267	192	16	14.1
Kentucky	1,539	536	792	211	65.2
Louisiana	2,479	818	515	1,146	67.0
Maine	509	37	60	412	92.7
Maryland	2,785	2,119	162	504	23.9
Massachusetts[2]	4,563	1,729	1,173	1,661	62.1
Michigan	6,377	1,340	4,223	814	79.0
Minnesota	2,370	769	1,324	277	67.6
Mississippi	988	460	23	505	53.4
Missouri[2]	3,141	2,522	183	436	19.7
Montana[1]	379	123	263		69.4
Nebraska[1] [2]	846	833	100		11.8
Nevada	376	366	6	4	2.7
New Hampshire	414	43	102	269	89.6
New Jersey	6,444	1,629	3,179	1,636	74.7
New Mexico	764	671	5	88	12.2
New York	16,003	8,017	3,733	4,253	49.9
North Carolina	2,138	1,447	125	566	32.3
North Dakota[1]	254	278	15		5.9
Ohio	7,870	4,591	2,071	1,208	41.7
Oklahoma	1,694	1,332	199	163	21.4
Oregon	1,320	552	504	264	58.2
Pennsylvania	8,428	325	2,916	187	36.8
Rhode Island	793	395	190	208	50.2
South Carolina	1,134	540	178	416	52.4
South Dakota[1]	287	290	39		13.6
Tennessee	2,214	750	319	1,145	66.1
Texas	8,874	6,819	130	1,925	23.2
Utah	825	500	19	306	39.4
Vermont	162	9	121	32	94.4
Virginia	2,756	1,092	1,328	336	60.4
Washington[2]	2,139	681	444	1,014	68.2
West Virginia	710	149	348	213	79.0
Wisconsin	2,804	2,049	689	66	26.9
Wyoming[1] [2]	198	189	29		14.6

[1] *Population served by treatment facilities exceeds total urban population of these States by 259,000 persons. Thus the detail adds to 259,000 more than the total U. S. urban population.*

[2] *Water quality standards adopted call for primary waste treatment in some urban areas of State. Standards adopted for other States call for at least secondary waste treatment.*

Source: 1962 Inventory, Municipal Waste Facilities in the United States, updated by FWPCA Construction Grants Awards; urban population estimates based on U. S. Census of Population, 1960; Bureau of Census Population Estimates, Series P-25.

Ohio - $461.7 million, Illinois - $367.0 million, Florida - $347.0 million, Texas - $323.6 million, Pennsylvania - $310.9 million, and Georgia - $209.6 million.

The five highest ranking Water Resource Council Regions (proposed for Type I Comprehensive Surveys) in capital outlays required to attain adequate waste treatment by 1973 are, in order: North Atlantic - $2,392.2, Great Lakes - $1,059.2, South Atlantic/Gulf - $921.9, Ohio - $674.6, and California - $647.8.

Table I-2 shows the per capita construction costs of primary and secondary sewage treatment plants. These data are based on design and cost information for sewage treatment projects constructed in all parts of the Nation under PL-660. The costs of treatment plant, interceptor, and outfall sewers are included; land costs are excluded because of the great variability. The per capita costs are shown in 1968 dollars arrived at by use of the FWPCA Sewage Treatment Plant Construction Cost Index.[7]

It is evident from these data that it is more economical in terms of cost per person served to construct a large rather than a small plant, assuming other things are equal. This conclusion assumes excessive sewering costs are not incurred, the topography is suitable for the extension of sewers, and the economics of scale available by constructing a larger or an intermunicipal plant are not offset by financing or operating costs.

Treatment works construction cost totals in a particular area may be reduced on a per capita basis when it is possible and desirable to serve many communities with a single or a few large treatment works. Economies of scale may also be available when industries and communities jointly construct treatment works to serve their needs.

The chief feature of sewage service in the large cities is centralized sewer lines and treatment.[8] Such systems can often provide waste treatment service to fringe communities at a lower overall cost than the communities would incur in constructing and operating individual systems. However, individuals and communities outside the central city contracting for service almost always pay a higher rate than customers within the city boundaries.

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[7] *Sewage Treatment Plant Construction Cost Index*, prepared by the Federal Water Pollution Control Administration, Division of Construction Grants, Washington, D. C.

[8] "Intergovernmental Responsibilities for Water Supply and Sewage Disposal in Metropolitan Areas," A Commission Report, Advisory Commission on Intergovernmental Relations, October 1962.

Communities without plants may be served by some form of special district, authority, or other arrangement including tie-ins with a central city. Economies of scale - the lower costs per unit of scale or design attributable to large scale plants - therefore, are not necessarily restricted to or solely available to the larger communities. Scale advantages can often be obtained through inter-community arrangement or through the legal establishment of new service area jurisdictions.

The larger inter-community and service area jurisdictions not only allow economies of scale in the construction of treatment plants, but attain an enlarged financial base as well. The latter may considerably alleviate, financing difficulties. In addition, the broader financial base offers the opportunity for higher quality operation through the acquisition of a larger and more competent staff.

The greatest offset to the economies of scale approach to sewage treatment construction for inter-community and new area service is the cost of the large trunk or interceptor sewers involved. These sewers are necessary to carry the wastes from the several collection points or from new and relatively distant area services to the treatment plant. Depending on the density of development and the nature of the terrain, the trunk sewer costs may be considerable, and at some point sufficiently high to offset any savings in treatment plant size. This factor looms large in the central city's determining whether extending sewerage service to adjacent communities is financially feasible. Also, the apportionment of trunk sewer costs poses a major difficulty.

OPERATION AND MAINTENANCE COSTS OF MUNICIPAL WASTE TREATMENT PLANTS

This report has estimated the capital costs of municipal waste treatment works construction needed to attain water quality standards at approximately $8.0 billion during the period 1969-1973, or as much as $8.7 billion because of increasing construction costs. Operating and maintaining these and the existing facilities will cost another $1.4 billion in this same period (Table I-5). If expected increases in labor costs during the period 1969-1973 are taken into consideration, these costs nationally could amount to $1.7 billion.[9] Thus operation and maintenance costs for the five-year period and capital outlays for new facilities would total $9.4 billion in constant 1968 dollars or $10.4 billion because of expected cost increases. Operation and maintenance totals nationally are estimated as $201.5 million in 1968 (Table I-5). These annual costs would rise to $334.5 billion in 1973 under the projected construction schedule.

Table I-6 shows the operation and maintenance costs per capita for primary and secondary types of treatment. For design populations of 25,000 and more, the representative secondary type of treatment - activated sludge - is approximately twice the per capita cost of the representative primary type. These operation and maintenance costs are based upon the actual costs directly associated with plant operation and maintenance, excluding costs for central administration, billing and collection of sewer charges, and expenditures for capital maintenance according to Federal construction grant records.

The types of costs included are salaries and wages, electricity, chemicals and other supplies. The data for these costs were obtained from approximately 1,000 individual plants and were correlated with population served. Admittedly, these cost estimates lack precision. First, they are adversely affected by differences among plants in chlorination and sludge disposal practices. Second, they would be more meaningful if they could be compared against a standard of operation efficiency or some other performance index. Since the data merely show the relationship between cost and plant size obtained from experience of the audited plants, they also may not be representative of the most efficient plants. In short, these per capita costs are probably conservative. Nevertheless, they reflect the considerable burden incumbent upon units of government which must construct or expand treatment facilities as well as provide for their operation. The expected annual operating costs, in some cases, could exert a greater deterrent upon a local unit

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[9] *"Indexes of Output Per Man-Hour, Hourly Compensation, and Unit Labor Costs in the Manufacturing Sector, 1947-1966," U. S. Department of Labor, Bureau of Labor Statistics, Washington, D. C., June 1967.*

TABLE I-5

OPERATION AND MAINTENANCE COSTS OF EXISTING MUNICIPAL TREATMENT FACILITIES AND ESTIMATED OPERATION AND MAINTENANCE COSTS, PROJECTED FACILITIES, 1969-1973

(In millions of 1968 dollars)

State	1968	Total 1969-1973[1]
United States	$201.5	$1,390.0
Alabama	3.1	22.2
Alaska	1.8	9.5
Arizona	.8	8.6
Arkansas	1.7	8.8
California	11.2	99.5
Colorado	2.5	16.3
Connecticut	3.2	25.1
Delaware	.5	3.5
District of Columbia	3.3	27.8
Florida	6.1	52.5
Georgia	3.6	26.7
Hawaii	.5	4.6
Idaho	1.1	5.6
Illinois	16.5	91.4
Indiana	7.1	40.8
Iowa	4.2	21.0
Kansas	3.4	17.6
Kentucky	3.1	20.0
Louisiana	2.8	24.7
Maine	.4	4.9
Maryland	2.7	18.1
Massachusetts	2.8	30.4
Michigan	7.2	62.0
Minnesota	4.2	28.2
Mississippi	1.1	10.5
Missouri	3.2	34.0
Montana	.8	4.3
Nebraska	2.2	9.4
Nevada	.5	2.5
New Hampshire	.4	3.8

TABLE I-5 (CONT'D.)

State	1968	Total 1969-1973[1]
New Jersey	$ 7.3	$ 60.9
New Mexico	1.1	6.4
New York	20.2	143.8
North Carolina	4.4	25.1
North Dakota	.4	2.1
Ohio	13.3	84.2
Oklahoma	3.1	17.2
Oregon	2.6	16.9
Pennsylvania	12.3	73.3
Rhode Island	1.2	7.9
South Carolina	2.0	13.3
South Dakota	.9	4.3
Tennessee	2.5	21.7
Texas	11.2	72.2
Utah	1.2	8.9
Vermont	.5	2.5
Virginia	3.3	25.2
Washington	3.0	22.8
West Virginia	1.4	8.5
Wisconsin	7.2	36.5
Wyoming	.4	2.0

[1] *Total Operation and Maintenance costs for treatment works existing and needed during the five-year period, 1969-1973.*

Source: Based on 1962 Inventory of Municipal Waste Facilities, updated; Census of Population, 1960; Bureau of Census Population Estimates, Series P-25, FWPCA construction grants plant audits of Operation and Maintenance costs.

FIGURE I - 3

MUNICIPAL WASTE TREATMENT FACILITIES
OPERATION AND MAINTENANCE COSTS

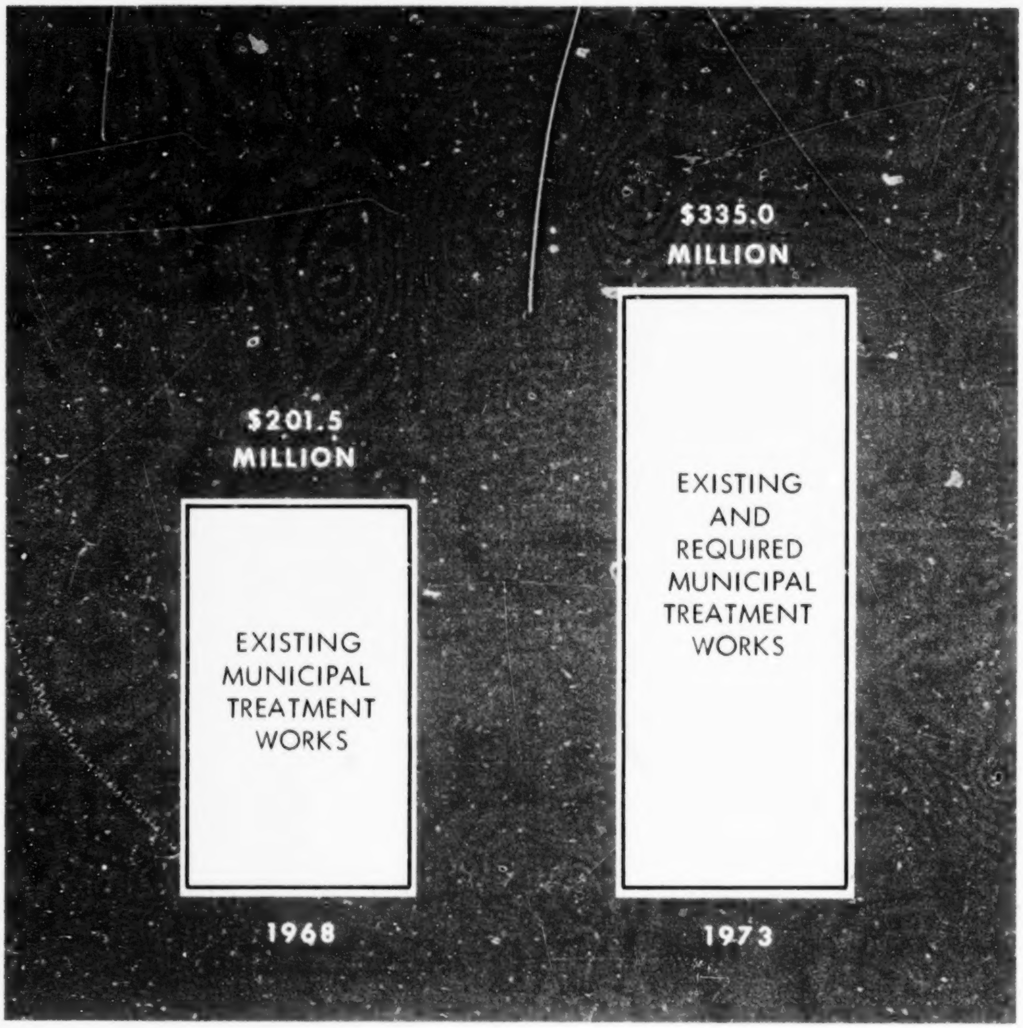

TABLE I-6

ANNUAL SEWAGE TREATMENT PLANT OPERATION AND MAINTENANCE PER CAPITA COST[1]

(1968 Dollars)

Design Population	Primary Types of Treatment (Separate Sludge Digestion	Secondary Types of Treatment	
		Activated Sludge	Stabilization Ponds
0 - 4,999	$3.00	$3.92	$.50
5,000 - 9,999	2.33	3.43	.34
10,000 - 24,999	1.84	3.06	
25,000 - 49,999	1.47	2.75	
50,000 - 99,999	1.29	2.51	
100,000 and up	1.22	2.45	

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[1] *Does not include costs for central administration, billing and collection of sewer charges, and expenditures for capital maintenance.*

Source: Based upon plant audits of actual operation and maintenance costs of sewage treatment projects constructed under PL 84-660.

of government initiating construction of a treatment plant than the construction cost.

Any evaluation of the effectiveness of water pollution control efforts will, in large part, be based upon the effectiveness and efficiency of the plants. In approving treatment works projects for Federal financial aid, FWPCA gives consideration to the adequacy of provisions for assuring proper and efficient operation and maintenance of the treatment works after construction. When this responsibility is not clearly understood or only tacit compliance given, water pollution increases because of poor plant maintenance, inadequately trained operators, inadequate operating supplies, and even cost reduction practices such as shutting down chlorination or chemical treatment equipment. Identifying these deficiencies requires expert appraisal. At present, water pollution control agencies at all levels of government lack adequate technical staffs to provide consultation services to the approximately 11,000 plants in operation. Operating inefficiencies must be identified, quantified and appropriate measures taken to obtain efficient sewage treatment plant operations if prescribed treatment levels are to be attained.

The Federal government provides no funds for operating, and only a few States either now provide such grants or are planning to do so. Such grants usually serve to improve operating efficiency of treatment facilities. New York State, for example, provides grants for one-third of the annual operating cost of municipal facilities, and requires the facilities to report regularly on operating efficiency. This type of state aid to local units of government may set the stage for increased efficiency by stimulating better control procedures, manpower training, and improved utilization of existing equipment.

Operating treatment plants more efficiently has been advanced as one way of increasing available capacity. However, an activated sludge plant, for example, operating at less than 85-95% BOD_5 (five-day biochemical oxygen demand) removal may nevertheless be utilizing its total hydraulic capacity. A plant designed for "x" mgd (million gallons per day) cannot accept a substantially greater volume of wastewater whether or not it is efficiently removing BOD_5. Table I-7 reflects BOD_5 removal efficiencies of various types of waste treatment facilities.

Bypassing and peak hour hydraulic loads imposed on a facility often adversely affect average hourly efficiency. Many facilities operating at 85-95% BOD_5 removal in non-peak hours fall to less than 60% BOD_5 removal during the peak noon hours. Although some plants may operate below capacity at night, the unused capacity is usually not readily available to more distant communities. In some situations, however, an industry discharging to public sewers can advantageously limit its waste discharges to these off-peak periods at municipal treatment plants.

TABLE I-7

RELATIVE EFFICIENCIES OF SEWAGE-TREATMENT OPERATIONS AND PROCESSES

(Percentage Removal)

Treatment Operation or Process	Five-day 20 C BOD
1. Fine screening	5-10
2. Chlorination of raw or settled sewage	15-30
3. Plain sedimentation	25-40
4. Chemical precipitation	50-85
5. Trickling filtration preceded and followed by plain sedimentation	80-95
6. Activated-sludge treatment preceded and followed by plain sedimentation	85-95
7. Intermittent sand filtration	90-95

Source: *Fair and Geyer, Water Supply and Wastewater Disposal, 5th edition, 1963, John Wiley & Sons, Table 21-11.*

COMBINED SEWERS

The control of pollution from municipal wastes is frequently complicated by the use of a single system to carry both sewage and surface storm runoff, referred to as a combined sewer system. Combined sewers carry sanitary sewage with its component commercial and industrial wastes at all times and, during storm or thaw periods, serve as collectors and transporters of storm water from streets and other sources thus serving a "combined" purpose. These combined systems are designed to carry many times the dry weather flow, because of the storm water. It has not been considered economically feasible to build intercepting sewers and treatment plants to handle the entire runoff along with the sewage flows. Therefore, combined sewers make provision for the transport of excess amounts of flow from the combined system directly to the stream, bypassing the treatment plant.

Separation of combined sewers into sanitary sewers and storm sewers has been considered the principal method of controlling pollution from this source. However, the cost of separating sewers completely would be enormous - recent estimates say $49 billion nationally. Moreover, this is not feasible, either economically or for effectively solving the problem. Sewer separation would involve major and prolonged disruptions to traffic and other street activities, and in the use of other utilities where electric conduits, water and gas mains, telephone and telegraph conduits, etc., are installed beneath the streets. Further, studies have shown that urban storm water itself, even when separated, carries serious pollution. It is clear, therefore, that sewer separation in itself provides no complete answer to the combined sewer overflow problem.

The solutions of pollutional problems caused by combined sewer systems may be as varied as the circumstances involved. In some situations, partial or complete separation may be the most feasible alternative. In other cases, the solution may be the construction of holding tanks or additional treatment facilities for handling such overflows.

PARTIAL OR COMPLETE SEPARATION

Separating a large combined sewer system into a dual system is a project of vast proportions. In some cases, new sanitary sewers would be required, leaving the existing sewers for storm water only. The converse may apply in other cases. To effect "total" separation of combined sewers, the plumbing within each building also would have to be rearranged so that roof leaders, areaway, depressed driveway and cellar drains would all discharge through a building connection into the storm drain. The sanitary sewage would discharge to another connection leading to the sanitary sewer.

A recent survey was made of the problems of combined sewer facilities and overflows in U. S. communities, by the American Public Works Association Research Foundation under contract with the Federal Water Pollution Control Administration.[10] Its purpose was to determine the national extent and effects of such overflows and report on the treatment measures or other controls, existing or planned, for abating the problem. All communities of 25,000 or greater population and 30% of those under 25,000 were interviewed. National totals were projected.

In the surveyed communities, 51 million people are served by partially or wholly combined sewers. Extrapolation by the survey indicates that in the total United States, 54 million people live in such municipalities. A 1964 appraisal[11] reported 59 million people in communities served by combined sewers. Because of the greater detail collected by the survey, the lower figure of 54 million would seem more precise. Excluding the appropriate portions of those communities served by separate sewers, an estimated 36 million people in the United States are actually served by combined sewer systems.

In addition to treatment plant overflows caused by storm water, other types of overflows may also be considerable in community sewer systems. Insufficient treatment plant capacity, infiltration, malfunctioning, poor maintenance of control devices, and pumping station bypasses are definite factors in the overflow problem.

According to the Survey, engineers have preferred to provide separate conduits for sanitary sewage and storm water rather than to enlarge or improve combined sewer systems.

Of the 641 jurisdictions surveyed, approximately one-half reported that engineering studies to correct pollution problems resulting from combined sewers or storm water overflows had been completed. Of these, 71% had prepared cost estimates. Of those with current plans, 71% planned to undertake some degree of sewer separation and the remaining 29% had plans for alternate corrective measures. This probably indicates that adequate information on the cost and effectiveness of alternates to sewer separation is not available.

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[10] *Problems of Combined Sewer Facilities and Overflows - 1967*, prepared by the American Public Works Association, December 1, 1967.

[11] "Pollutional Effects of Storm Water and Overflows From Combined Sewer Systems, A Preliminary Appraisal," prepared by the Division of Water Supply and Pollution Control, Public Health Service, U. S. Government Printing Office, Washington, D. C., 1964.

To facilitate cost evaluation, the 49 states (Hawaii reported no combined sewers) and the District of Columbia were grouped into seven geographic regions:

(1) New England: Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, Vermont

(2) Middle Atlantic: Delaware, New Jersey, New York, Pennsylvania

(3) South Atlantic: District of Columbia, Maryland, Virginia, West Virginia

(4) Southern: Alabama, Arkansas, Florida, Georgia, Kentucky, Louisiana, Mississippi, North Carolina, South Carolina, Tennessee

(5) Midwest: Illinois, Indiana, Iowa, Kansas, Michigan, Minnesota, Missouri, Nebraska, North Dakota, Ohio, South Dakota, Wisconsin

(6) West: Alaska, California, Colorado, Idaho, Montana, Nevada, Oregon, Utah, Washington, Wyoming

(7) Southwest: Arizona, New Mexico, Oklahoma, Texas

The cost evaluations as developed utilized information from the survey forms, supplemented by additional information obtained from surveyed communities. Area and population data were extracted and dollar-per-capita and dollar-per-acre ratios were developed for each community for the combined-sewer area and population affected.

Regional and national figures developed show the range of costs for complete separation (Table I-8). Mean and median values are also determined on the bases of dollars-per-capita and dollars-per-acre. The cost estimates for "complete separation" refer to separating the entire combined sewer system, but do not include the necessary plumbing changes on private property to effect "total" separation. As expected, there were large variations in the costs reported. Most ranges, however, confirmed the reasonableness of the values ascribed to complete separation. It is important to note that many metropolitan communities, such as Chicago, Cleveland, Detroit, New York, Portland, and Rochester, submitted no separation cost data in this survey, perhaps because the probability of such work is remote. These cities have high population densities and are heavily industrialized. In many large cities, conventional separation is all but impossible because of existing tremendous under-street development - pipes, subways, and other utilities.

TABLE I-8

REPORTED COST OF SEPARATION BY REGION

Area	Complete Separation[1]					
	Cost Per Acre			Cost Per Capita		
	Range	Mean	Median	Range	Mean	Median
New England	$5,800-55,800	$19,000	$10,000	$480-1,160	$ 700	$630
Middle Atlantic	4,550-42,900	13,000	11,000	430-2,720	1,125	640
South Atlantic	6,700-27,500	13,100	7,300	415-1,250	790	750
Southern	1,420-27,500	8,930	5,450	445-1,220	670	510
Midwest	100-29,000	5,720	3,590	25-2,660	630	415
West	290-16,700	4,940	1,700	60-5,000	600	280
United States	$ 100-55,800	$ 6,740	$ 4,500	$ 25-5,000	$ 670	$470

[1] *"Complete Separation" means the elimination of combined flows for the entire sewer system by providing two separate public sewer systems in streets and other public areas, but not including any separation work on private property.*

Source: Problems of Combined Sewer Facilities and Overflows - 1967, prepared for FWPCA by the American Public Works Association, Table IX-B, 1967.

The absence of cost data from these metropolitan areas may have resulted in a lower cost range because of the predominance of less costly procedures in less developed and less concentrated urban areas.

The only reliable cost information on separating plumbing to private and commercial buildings was in the Washington, D. C. data. The District of Columbia, for several years, has had an intensive program of working on a voluntary basis with property owners in selected areas to disconnect, from the sanitary system, downspouts, roof drains, foundation drains, areaway drains, air conditioning and cooling system drains, yard drains, catch basin drains and other connections not receiving sanitary sewage. Unit costs developed for various single family type dwellings vary from $890 for a row house to $3,480 for homes on one-half acre lots. Limited experience has been gained in separating commercial and apartment buildings. Costs to date range from $100 to $50,000 per unit. For the purpose of cost projections, the figures of $1,700 for a single-family dwelling and $3,400 for an apartment building or commercial structure were selected. These costs were adjusted for each area on the basis of the Engineering News Record cost index for sewer construction as of September 1967.

Projections of cost were made for each state. Only limited data were available for many of the states, and it was necessary to base projections for these on national cost figures and housing data. Table I-9 shows the cost estimates for separation of the public and private portions of combined sewers. For the United States, "total" separation of combined sewers would cost an estimated $48.8 billion; separation of only the public part would cost $30.4 billion.

HOLDING TANKS

There are wide variations in the extent and characteristics of holding tank projects. No uniformity in design criteria is apparent. Some tanks may be designed for short-time balancing to control surcharging while others are designed for partial treatment of the overflow by settling and chlorination. In 1964 the Public Health Service published available cost information for holding tanks for temporary impoundment of storm water discharges and/or combined sewers overflows.[12] The per capita cost of these projects, $318, was used to estimate cost of holding tanks as an alternative to combined sewer separation. These estimated costs are listed by State in Table I-9, with the total cost for the United States estimated at $11.6 billion.

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[12] *"Pollution Effects of Storm Water and Overflows From Combined Sewer Systems, A Preliminary Appraisal,"* *loc. cit.*

TABLE I-9

ESTIMATED COST OF SEPARATION OF COMBINED SEWERS AND THE ALTERNATIVE OF HOLDING TANKS

State	Population Served By Combined Sewers[1] (Thousands)	COST OF SEPARATION[2] ($ Million)			Cost of Holding Tanks[5] ($ Million)
		Separation of Public Part of Combined Sewers[3]	Plumbing Charges to Affected Buildings[4]	Total	
United States	36,394	$30,391.6	$18,378.3	$48,769.9	$11,573.3
Alabama	-	-	-	-	-
Alaska	10	8.3	4.0	12.3	3.2
Arizona	-	-	-	-	-
Arkansas	31	25.7	23.3	49.0	9.8
California	854	712.0	547.0	1,259.0	271.6
Colorado	42	35.4	17.0	52.4	13.5
Connecticut	447	373.0	146.0	519.0	142.1
Delaware	97	81.3	52.6	133.9	30.9
District of Columbia	400	334.0	119.0	453.0	127.2
Florida	4	3.7	1.5	5.2	1.4
Georgia	379	317.0	191.9	508.9	120.6
Hawaii	-	-	-	-	-
Idaho	19	15.8	.3	16.1	6.0
Illinois	5,103	4,270.0	2,420.0	6,690.0	1,622.9
Indiana	2,038	1,710.0	872.4	2,582.4	648.2
Iowa	390	326.0	188.8	514.8	124.0
Kansas	131	109.5	46.0	155.5	41.6
Kentucky	587	490.0	264.4	754.4	186.7
Louisiana	-	-	-	-	-
Maine	293	243.0	116.5	359.5	93.2
Maryland	23	19.5	4.5	24.0	7.4
Massachusetts	1,707	1,425.0	926.3	2,351.3	542.9
Michigan	2,913	2,430.0	1,548.5	3,978.5	926.2
Minnesota	506	423.0	189.6	612.6	161.0
Mississippi	2	1.3	.1	1.4	.5
Missouri	1,166	972.0	605.0	1,577.0	370.7
Montana	25	21.0	7.4	28.4	8.0
Nebraska	314	263.0	96.7	359.7	100.0
Nevada	40	33.0	6.8	39.8	12.6
New Hampshire	236	196.0	106.4	302.4	74.9
New Jersey	1,185	990.0	753.5	1,743.5	376.9
New Mexico	-	-	-	-	-
New York	8,519	7,100.0	4,366.0	11,466.0	2,708.9
North Carolina	8	6.3	1.4	7.7	2.4
North Dakota	77	64.3	17.4	81.7	24.5
Ohio	2,880	2,410.0	1,532.8	3,942.8	915.7
Oklahoma	-	-	-	-	-
Oregon	445	372.0	219.0	591.0	141.5
Pennsylvania	2,757	2,300.0	1,396.5	3,696.5	876.8
Rhode Island	277	231.0	204.7	435.7	88.1
South Carolina	-	-	-	-	-
South Dakota	20	16.6	8.2	24.8	6.3
Tennessee	207	173.0	111.7	284.7	66.0
Texas	83	69.0	42.8	111.8	26.3
Utah	-	-	-	-	-

TABLE I-9 (CONT'D.)

State	Population Served By Combined Sewers[1] (Thousands)	COST OF SEPARATION[2] ($ Million)			Cost of Holding Tanks[5] ($ Million)
		Separation of Public Part of Combined Sewers[3]	Plumbing Charges to Affected Buildings[4]	Total	
Vermont	139	116.5	28.2	144.7	44.4
Virginia	273	228.0	128.4	356.4	86.7
Washington	730	610.0	478.0	1,088.0	232.2
West Virginia	335	280.0	179.1	459.1	106.4
Wisconsin	700	585.0	408.0	993.0	222.6
Wyoming	2	1.4	.6	2.0	.5

[1] Population served by combined sewers in communities with completely combined sewer systems and population actually served by the combined portion of sewers systems in communities with both combined and separate sewers.

[2] Estimated by American Public Works Association.

[3] Complete separation of combined sanitary and storm flows by providing two separate public sewer systems in streets and other public areas.

[4] Separation of plumbing within buildings, roof downspouts and leaders, foundation drains connected to combined sewers, areaway drains, air conditioning and cooling systems, and improper connections.

[5] Cost based on $318 per capita cost as shown in *Pollutional Effects of Stormwater and Overflows From Combined Sewer Systems*, Table XVII, PHS No. 1246, 1964.

Source: *Pollutional Effects of Stormwater and Overflows From Combined Sewer Systems*, Public Health Service; "Problems of Combined Sewer Facilities and Overflows - 1967," prepared for FWPCA by the American Public Works Association.

Based on the limited data available in the 1967 national survey[13] it was estimated that the alternate means of control and/or treatment other than sewer separation would cost approximately $15 billion.

The holding tank estimate should be used with extreme caution. Data reported in the recent survey[14] were insufficient to substantiate or refute the per capita cost of $318 estimated for holding tanks; however, the reported costs ranged from $62 to $1,300 per capita. It should be noted that holding tanks have been used only in areas of low land costs, while 44% of the combined sewer outfalls are located in heavily commercial and/or industrial areas where land costs would be prohibitive.

Chicago is presently constructing approximately five miles of concrete-lined underground tunnel at a depth of 200 to 250 feet for storage of combined sewer overflows. Such a system has special application in highly developed urban areas where surface storage is uneconomical and public inconvenience must be minimized. The present estimated cost is $96 per capita or $3,975 per acre.

In contrast, the stabilization pond being used by Springfield, Illinois is much smaller in total magnitude than Chicago's deep tunnel. In Springfield, with land readily available, the estimated cost of the pond is $7 per capita or $96 per acre.

New York City has released information on plans to approach the storm overflow problem by constructing a series of specialized overflow treatment facilities located at critical points throughout the city which would process the large amounts of combined sewer overflows resulting from rainstorms. Construction of 30 such small treatment plants is estimated to cost about $460 million. Construction is scheduled to begin in 1968 on the first of these auxiliary water pollution control plants at Spring Creek on Jamaica Bay. The present estimated cost for this first plant is $69 per capita or $3,220 per acre. Additional small plants will be constructed if the Jamaica Bay unit proves successful.

Pollution from the discharges of sewers carrying storm water and sewage or other wastes, has been recognized as a significant problem in attaining water quality standards. Congress, late in 1965, authorized FWPCA to assist demonstrations and studies which will provide a better understanding of the problems of combined sewers through detailed engineering evaluations embodying complete economic analyses. The authorization was amended by the Clean Water Restoration Act of 1966. Section 6a(1) of the Federal Water Pollution Control Act, as amended, authorizes grants to any state, municipality, or intermunicipal or interstate agency for the purpose of assisting in the development of any project which will demonstrate a new or improved method of controlling the discharge into any waters of untreated or inadequately treated sewage or other waste from sewers which carry storm water or both storm water and sewage or other wastes. Contract research and development in this technical area are also authorized. The principal objective is to provide funds to develop engineering and economic data on the alternative methods for control and/or treatment of these forms of pollution. Projects thus funded are expected to demonstrate a variety of new or improved methods and to stimulate industry-wide application of the demonstrated facilities.

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[13] *Problems of Combined Sewer Facilities and Overflows - 1967*, *loc. cit.*

[14] *"Pollution Effects of Storm Water and Overflows From Combined Sewer Systems, A Preliminary Appraisal," loc. cit.*

In summary, nationwide elimination of combined sewers by means of separation would be very costly and impose heavy burdens on local and State governments. "Total" separation would cost $48.8 billion; separation of only the public part would cost $30.4 billion, and would not include the rearrangement of plumbing to affected buildings and homes. As an alternate solution, a complete system of holding tanks is estimated to cost $11.6 billion. Without delineating the various types, the 1967 survey estimated that alternate methods would cost approximately $15 million. Alternatives to separation for the control and/or treatment of combined sewer overflows, such as holding tanks, treatment facilities or other control means, may reduce the pollution effects of the problem to acceptable levels. Still other alternatives may be discovered to the methods presently being investigated by FWPCA's Storm and Combined Sewer Pollution Control Program, designed to develop engineering evaluations and economic analyses of new and improved methods for the control and/or treatment of combined sewer overflows.

The final solution will no doubt be a combination of various control and/or treatment methods, including sewer separation, resulting from detailed engineering and socio-economic studies for individual problem areas.

SEPARATE SANITARY SEWERS

The cost of providing separate sanitary sewers for the unsewered urban population and the cost of sewering increases in urban population has been estimated by this study for the period 1969-1973, in order to relate these requirements to waste treatment works requirements. Estimates of the capital costs of these needs have been included because of their basic relation to municipal waste treatment needs.

Separate sanitary sewers are needed by a large number of communities presently without sewers, and existing separate sanitary sewers must also be expanded in the next five years in order to serve increasing population and urbanization.

Interceptor sewer requirements are included as part of waste treatment works needs because these sewers are an integral aspect of waste treatment systems and therefore eligible for FWPCA construction grants. However, the distinction between interceptor and a trunk collecting sewers must be made on almost a case-by-case basis to determine their eligibility for Federal grant funds. The inclusion of collection sewer requirements can lead to over-estimates of treatment needs.

Separate sanitary sewers carry wastewater but are designed to exclude storm and surface waters. Such sewers are single-purpose systems for collecting and transporting all of a community's waterborne wastes to the treatment plant via a collector or interceptor sewer before the treated effluent is discharged to a receiving waterbody. Separate storm sewer systems collect, convey, channel and transport all storm water runoff directly to a stream or other receiving waterbody.

This study assumes that the national need for sanitary sewers is based upon the total urban population in each State and Water Resource Region. The cost of constructing sanitary sewers varies widely throughout the United States. In 1963 the sewering of unsewered areas served by public water systems, was estimated by FWPCA at $125 per capita. This cost figure, adjusted for interim construction cost changes by States, was used to calculate the total costs for sewering the unsewered urban population for each State, and for sewering projected urban population growth during the period 1969-1973. An estimated 28.4 million persons presently live in unsewered urban communities.

The cost for new sanitary sewers would total $6.2 billion. Of this amount, $3.9 billion would be required to sewer the presently unsewered urban population, and $2.3 billion for sewering urban population increases in the period 1969-1973. Table I-10 is a summary of capital outlay needs by State and Water Resource Regions.

This study makes no attempt to calculate the capital costs of storm sewers required for U. S. urban areas. The American Public Works Association has estimated such capital outlays at $25 billion to finance the storm water facilities needed in new and expanding urban areas and to overcome present urban area deficiencies during the decade 1966-1975.[15]

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[15] *"Urban Drainage Practices, Procedures and Needs," prepared by the American Public Works Association Urban Drainage Committee, December 1966.*

TABLE I-10A

CAPITAL OUTLAYS NEEDED FOR CONSTRUCTION OF SANITARY SEWERS FOR THE U. S. URBAN POPULATION, 1969-1973

($ Millions)

State	Total Capital Outlays	Capital Outlays: Reduce Current Unmet Need	Capital Outlays: Increases In Urban Population
United States	$6,160.5	$3,867.0	$2,293.5
Alabama	65.0	37.5	27.5
Alaska	8.0	3.0	5.0
Arizona	133.5	81.5	52.0
Arkansas	24.5	6.5	18.0
California	1,174.5	718.0	456.5
Colorado	52.0	17.0	35.0
Connecticut	125.0	94.5	30.5
Delaware	19.5	11.5	8.0
District of Columbia	53.5		53.5
Florida	368.5	252.5	116.0
Georgia	104.0	48.5	55.5
Hawaii	73.0	62.0	11.0
Idaho	9.0	4.5	4.5
Illinois	210.5	118.0	92.5
Indiana	67.0	34.5	32.5
Iowa	12.5		12.5
Kansas	20.5		20.5
Kentucky	48.5	24.5	24.0
Louisiana	143.0	95.0	48.0
Maine	4.0	2.0	2.0
Maryland	115.5	65.5	50.0
Massachusetts	200.5	173.5	27.0
Michigan	192.0	118.5	73.5
Minnesota	75.0	36.5	38.5
Mississippi	41.5	27.5	14.0
Missouri	293.0	257.5	35.5
Montana	5.5		5.5
Nebraska	17.5	7.0	10.5
Nevada	16.0		16.0
New Hampshire	19.0	13.5	5.5
New Jersey	386.5	273.0	113.5
New Mexico	33.0	11.5	21.5
New York	637.0	466.5	170.5
North Carolina	76.0	40.5	35.5
North Dakota	5.0		5.0
Ohio	247.0	159.0	88.0
Oklahoma	42.5	17.0	25.5
Oregon	67.0	37.5	29.5
Pennsylvania	46.0		46.0
Rhode Island	33.0	27.5	5.5
South Carolina	34.5	18.5	16.0
South Dakota	4.0		4.0
Tennessee	66.5	42.0	24.5
Texas	378.5	211.0	167.5
Utah	51.0	32.5	18.5
Vermont	2.0		2.0
Virginia	110.0	47.5	62.5
Washington	186.5	154.5	32.0
West Virginia	13.5	9.5	4.0
Wisconsin	45.0	8.5	36.5
Wyoming	4.5		4.5

Source: *Based on 1962 Inventory of Municipal Waste Facilities, updated; Sixth Annual Survey of Municipal Waste Treatment Needs by CSSE, January 1966.*

TABLE I-10B

CAPITAL OUTLAYS NEEDED FOR CONSTRUCTION OF SANITARY SEWERS FOR THE U. S. URBAN POPULATION, 1969-1973
($ Millions)

Water Resource Region[1]	Total Capital Outlays	Capital Outlays	
		Reduce Current Unmet Need	Increases In Urban Population
Alaska	8.0	3.0	5.0
Arkansas-White-Red	164.2	79.7	84.5
California	1,175.8	718.7	457.1
Columbia-North Pacific	263.1	195.7	67.4
Great Basin	52.7	29.2	23.5
Great Lakes	464.1	282.5	181.6
Hawaii	73.0	62.0	11.0
Lower Colorado	145.8	83.1	62.7
Lower Mississippi	155.8	103.9	51.9
Missouri	220.3	141.3	79.0
North Atlantic	1,632.9	1,101.2	531.7
Ohio	281.2	159.7	121.5
Rio Grande	61.3	28.5	32.8
Souris-Red-Rainy	4.0	.7	3.3
South Atlantic-Gulf	680.9	418.1	262.8
Tennessee	29.0	17.8	11.2
Texas-Gulf	325.4	180.7	144.7
Upper Colorado	6.9	3.0	3.9
Upper Mississippi	416.1	258.2	157.9

[1] *Water Resource Regions proposed by Water Resource Council for Type I Comprehensive Surveys. Data were not available to estimate capital outlay needs for the Puerto Rico-Virgin Islands Region.*

Source: Based on 1962 Inventory of Municipal Waste Facilities, updated; Sixth Annual Survey of Municipal Waste Treatment Needs by CSSE, January 1966.

INDUSTRIAL DISCHARGE TO PUBLIC SEWERS

Industrial wastewater discharged to public sewers may increase substantially in the next few years as water quality standards are implemented. Industries which are required to upgrade waste treatment may find it economically desirable to enter into joint agreements with municipalities to construct treatment facilities. Such combined industrial-municipal treatment could yield savings in capital and operating costs to both community and industry.

The most recent detailed data on industrial discharges to public sewers are contained in the 1964 Census of Manufactures, "Water Use in Manufacturing".[16] The census shows water intake for establishments reporting annual water intake of 20 million or more gallons and the amount of wastewater they discharge to public utility sewers, as well as the water intake for the establishments reporting water intake of under 20 million gallons annually. Discharges to public sewers by the latter establishments were not reported by the census.

Water discharged to public sewers by those establishments using more than 20 million gallons decreased from 997 billion gallons in the 1959 Census to 987 billion gallons in the 1964 Census, a drop of 1%. However, if present trends, state-by-state continue, the national aggregate will increase. This is explained by the upward trends in some States that have large industrial discharges to public sewers. Extrapolating these trends to 1968 shows the large-user discharges to public sewers increasing to 1,029.0 billion gallons. Continuing the trend to 1973 would raise this discharge to 1,157.2 billion gallons.

Although the 1964 Census of Manufactures did not show the amount of wastewater discharged to public sewers by those industrial establishments using under 20 million gallons of water annually, it was assumed that this water was discharged to public sewers. This assumption was made because 80% of the 119,714 establishments in this category actually used under one million gallons each per year, and only 4% used from 10-20 million gallons. Furthermore, an establishment with an intake of one million gallons would be using only about 2,740 gallons per day, roughly equal to the water used daily by 34 people. In view of the small amount of water use by 80% of these establishments, it is unlikely that they have installed their own wastewater treatment equipment. Even a factory using more than 10 million gallons annually (the 4% group) would be using only about the same amount of water daily as 500 persons. Some, though certainly not all, of this latter group may have wastewater treatment equipment. Also, a few are probably discharging wastewaters directly to streams. Overall, it seems reasonable for purposes of this study, to consider that all wastewater discharged by establishments using less than 20 million gallons of water annually goes to public sewers.

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[16] *"Water Use in Manufacturing," 1963 Census of Manufactures, prepared by the Bureau of the Census, U. S. Department of Commerce, U. S. Government Printing Office, Washington, D. C., 1966.*

The annual water intake for the under-20-million-gallon users was extrapolated to 1968 by using the average annual value added by manufacture for establishments in each State. The data were further extrapolated to 1973 by the trend in value added by manufacture in each State. By this method it was estimated that the under-20-million-gallon users will discharge an estimated 310 billion gallons of wastewaters to public sewers in 1968, with an expected rise to 455 billion gallons in 1973.

By 1973, the total discharges are projected to increase 20%, the discharges of the over-20-million-gallon users by 12%, and those of the under-20-million-gallon group by 47%.

Table I-11 shows the industrial water discharged to public sewers by Water Resource Regions. Ranking first is the North Atlantic Region, discharging 336.1 billion gallons in 1968; second is the Great Lakes Region, discharging 244.9 billion gallons; third is the Upper Mississippi Region, discharging 200.7 billion gallons; and fourth the Ohio Region, discharging 177.9 billion gallons. From 1968 to 1973 the increases are fairly consistent from Region to Region except for the Columbia-North Pacific Region which shows a decrease of 0.3%. It is probably that industrial wastewater discharged to public sewers will increase substantially under pressures for water quality standards compliance because this could offer economies to a manufacturer otherwise faced with installing or expanding his own water pollution control facilities.

Waste treatment service provided by local governments for industrial concerns is feasible and desirable when based on equitable payment arrangements. The advantages to industry include avoidance of capital investments, the economies of scale, and the convenience. There are advantages to local governments in strengthened financial bases of operation, in the economies of scale, and in increased opportunity for pollution surveillance and monitoring of waste discharges for pollution control. The additional revenues to the local government, as a result of full-cost pricing of the service, could be used for improved operations and for participating in basinwide management systems. Moreover, a user-charge not only achieves more equitable prices and waste controls but also provides revenues which otherwise would have to be raised by taxes.

Many factors will influence the trend toward joint municipal-industrial waste treatment in the next few years. In individual cases, legal questions will have to be resolved concerning facility ownership, how the construction costs will be allocated, how operation and maintenance costs will be borne, and types and quantities of wastes treated.

TABLE I-11

INDUSTRIAL WATER DISCHARGED TO PUBLIC SEWERS PROJECTED FOR 1968 AND 1973, BY WATER RESOURCE REGION

(Billion Gallons)

Water Resource Region[1]	1968	1973	Percentage Change
United States	1,338.5	1,612.2	20.4%
Alaska	7.2	11.3	56.9
Arkansas-White-Red	33.8	46.7	38.2
California	80.3	99.6	24.0
Columbia-North Pacific	35.5	35.4	- .3
Great Basin	3.3	4.2	27.3
Great Lakes	244.9	296.3	21.0
Hawaii	3.5	5.5	57.1
Lower Colorado	1.6	2.6	62.5
Lower Mississippi	14.9	16.4	10.1
Missouri	60.1	77.0	28.1
North Atlantic	336.1	388.2	15.5
Ohio	177.9	218.0	22.5
Rio Grande	4.0	6.3	57.5
Souris-Red-Rainy	3.5	4.0	14.3
South Atlantic-Gulf	87.9	111.6	27.0
Tennessee	10.8	11.5	6.5
Texas-Gulf	31.7	51.7	63.1
Upper Colorado	.9	1.2	33.3
Upper Mississippi	200.7	224.7	12.0

[1] *Water Resource Regions proposed by Water Resource Council for Type I Comprehensive Surveys. Data were not available to estimate capital outlay needs for the Puerto Rico-Virgin Islands Region.*

Source: Projected on basis of trends reflected in Census of Manufactures, "Water Use in Manufacturing", 1959 and 1964, and trends in value added by manufacture in the respective states.

An actual contract between an industry and a municipality illustrates the nature of these agreements: an equitable distribution of initial capital savings as well as savings in operation costs; assurance by the city that operation of the treatment works would be separated from political appointments; agreement by the city that it would accept the company's wastewaters for treatment; agreement by the company that it would deliver its wastes to the city for treatment, and a guarantee by the company that it would not build a competitive plant; agreement by the company to furnish its pilot plant data to the city to use for the design basis; agreement by the city to hire the newly formed Sewage Treatment Company, a company subsidiary, to operate the city's sewage treatment works, reserving to the company the right to control employment; and specifications of financial details including cost-sharing and the establishment of service rates.[17]

Not all industrial wastes are amenable to the municipal waste treatment processes regardless of the willingness of communities and industry to cooperate in their joint waste treatment problems. Another factor to be considered is that some receiving streams may not be able to assimilate adequately the discharges from a large single treatment source. Part II of this Volume contains a detailed analysis of joint municipal-industrial waste treatment on an industry-by-industry basis.

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[17] *Gaudy, A. F., et al., Symposium on Joint vs. Separate Treatment of Municipal and Industrial Wastes, presented at the 13th Oklahoma Industrial Wastes Conference at Oklahoma State University, Stillwater, Oklahoma, November 28-29, 1966.*

SUMMARY

Providing waste treatment facilities for population growth, upgrading primary treatment works, constructing treatment works for the urban population presently unserved and replacing depreciated plants and equipment will cost $8.0 billion during the period FY 1969-1973. This cost could increase to $8.7 billion based upon the rising construction costs of recent years.

The waste treatment facilities, existing and projected, required to attain water quality standards over the next five years, will place substantial financial demands upon communities for operation and maintenance. These costs are estimated at $1.4 billion in the period FY 1969-1973. Labor cost increases could raise this amount to $1.7 billion.

In order to meet the standards by 1973, it is estimated that 90% of the urban population will require secondary treatment facilities and 10% primary treatment facilities.

Substantial additional costs will be incurred during the 1969-1973 period for the control of overflows from combined sewers. It is anticipated that a variety of control methods will be initiated, depending upon individual circumstances, and as a result, the full extent of these costs cannot be estimated at this time.

New sanitary sewers for the U. S. urban population projected to 1973 will cost $6.2 billion. This study has not attempted to calculate the capital needs for urban drainage improvements in the U. S. However, the American Public Works Association has estimated these capital needs at $25 billion for the period 1966-1975.

Future trends in industrial wastewater discharges to public sewers will be influenced greatly by the extent to which municipalities and industries can jointly and feasibly solve their waste treatment problems. Industry, spurred by requirements to comply with water quality standards, may find such a joint waste treatment operation advantageous. Economies of scale may also be available through municipal-industrial sharing of the construction costs of joint treatment works.

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BIBLIOGRAPHY

Advisory Commission on Intergovernmental Relations. *A Commission Report, Intergovernmental Responsibilities for Water Supply and Sewage Disposal in Metropolitan Areas*, Washington, D. C., October 1962.

American Public Works Association. *The Problems of Combined Sewer Facilities and Overflows, 1947*. A report prepared by the American Public Works Association, 1967 for the Federal Water Pollution Control Administration, U. S. Department of the Interior.

American Public Works Association, Urban Drainage Committee. *Urban Drainage Practices, Procedures, and Needs*. Project 119. Chicago, Illinois: December 1966.

Byrd, J. Floyd. *Combined Treatment - A Coast-to-Coast Coverage*. Paper presented at the 39th Annual Conference of the Water Pollution Control Federation in Kansas City, Missouri, September 25-30, 1966.

Conference of State Sanitary Engineers. *Second Annual Report on Municipal Waste Treatment Needs*. Conference of State Sanitary Engineers, January 1, 1962.

Conference of State Sanitary Engineers. *Sixth Annual Survey of Municipal Waste Treatment Needs*, Federal Water Pollution Control Administration, Public Health Service, Washington, D. C., January 1966.

Fair, G. M. and J. C. Geyer. *Water Supply and Wastewater Disposal*, John Wiley and Sons, Inc., Fifth Printing, New York, New York, April 1963.

Gaudy, A. F., *et al*. *Symposium on Joint vs. Separate Treatment of Municipal and Industrial Waste*. Symposium was presented at the 13th Oklahoma Industrial Wastes Conference at Oklahoma State University, Stillwater, Oklahoma, November 28-29, 1966.

Glass, Andrew C. and Kenneth H. Jenkins. *Statistical Summary of 1962 Inventory Municipal Waste Facilities in the United States*. Division of Water Supply and Pollution Control, U. S. Department of Health, Education and Welfare, Public Health Service. Washington 1964.

Haseltine, T. R. "A Rational Approach to the Design of Activated Sludge Plants." *Sewage Treatment*. Pages 257-270.

Howells, D. H. and D. P. Dubois. "The Design and Cost of Stabilization Ponds in the Midwest." Sewage and Industrial Wastes. Volume 31, No. 7, July 1959.

Kammerer, J. C. and K. A. Mackichan. Estimated Use of Water in the United States, 1960. U. S. Department of the Interior, Geological Survey, Geological Survey Circular 456, Washington, 1961.

Keefer, C. E. Sewage Treatment - How It Is Accomplished. From the Smithsonian Report for 1956. Smithsonian Institution, Washington, D. C. 1957. Pages 363-389.

Koenig, Louis. The Cost of Water Quality Control. Talk for Presentation at ASTM National Meeting on the Control of Water Quality. Philadelphia, Pennsylvania, May 13, 1965.

________. Studies Relating to Market Projections for Advanced Waste Treatment. For The Advanced Waste Treatment Research Activities, Research and Development, Cincinnati Water Research Laboratory, U. S. Department of the Interior, Federal Water Pollution Control Administration. Cincinnati, December 1966.

Logan, John A., W. D. Hatfield, George S. Russell, and Walter R. Lynn. "An Analysis of the Economies of Wastewater Treatment." Journal Water Pollution Control Federation. Volume 34, No. 9. September 1962. Pages 860-882.

National Academy of Sciences-National Research Council. Waste Management and Control. A Report to the Federal Council for Science and Technology by the Committee on Pollution, National Academy of Sciences. Washington, 1966.

National Association of Counties/Research Foundation. Community Action Program for Water Pollution Control. Washington, 1965.

National Association of Home Builders, Research Institute, in Cooperation With U. S. Department of Health, Education and Welfare, Public Health Service. Small Sewage Treatment Systems. Washington, 1959.

President's Science Advisory Committee, Restoring the Quality of Our Environment, A Report of the Environmental Pollution Panel, The White House, 1965.

Rafuse, Jr., Robert W. Water-Supply and Sanitation Expenditures of State and Local Governments: Projections to 1970. In cooperation with the National Association of Cojnties, the National League of Cities, the U. S. Conference of Mayors, The George Washington University. Chicago: The Council of State Governments, 1966.

Rowan, P. P., K. L. Jenkins, and D. H. Howells. Division of Water Supply and Pollution Control, U. S. Department of Health, Education and Welfare, Public Health Service. "Estimating Sewage Treatment Plant Operation and Maintenance Costs." Journal Water Pollution Control Federation. February 1961. Volume 33, No. 2.

State of Michigan, Joint Legislative Committee on Water Resources Planning. Study on Needs for Water Pollution Control Works. December 31, 1966.

Swanson, C. L. Unit Process Operating and Maintenance Costs for Conventional Sewage Treatment Processes, (unpublished memorandum) August 1, 1966.

U. S. Bureau of the Census, U. S. Census of Population: 1960, Volume I. U. S. Government Printing Office, 1961.

________. 1963 Census of Manufactures, Water Use in Manufacturing. Washington: U. S. Government Printing Office, 1966.

U. S. Congress, House, Joint Economic Committee, State and Local Public Facility Needs and Financing, 89th Congress, 2nd Session, Volumes 1 and 2, 1966.

U. S. Congress, Senate, Select Committee on National Water Resources. Water Resources Activities in the United States, Pollution Abatement. Committee Print No. 9. 89th Congress, 2nd Session, 1960.

U. S. Congress, Senate, Steps Toward Clean Water. Washington, D. C. January 1966.

U. S. Congress, Senate, Committee on Public Works, Hearings Before a Special Subcommittee on Air and Water Pollution, 89th Congress, 1st Session, Parts 1, 2 and 3, 1965.

U. S. Department of Commerce. Regional Construction Requirements for Water and Wastewater Facilities, 1955-1967-1980. Business and Defense Services Administration. Washington, 1967.

U. S. Department of Health, Education, and Welfare, Public Health Service. Modern Sewage Treatment Plants - How Much Do They Cost? Division of Water Supply and Pollution Control. Washington, 1965.

________. Pollutional Effects of Storm Water and Overflows From Combined Sewer Systems, A Preliminary Appraisal. Division of Water Supply and Pollution Control. Washington, 1964.

________. Proceedings the National Conference on Water Pollution. Washington, D. C. December 12-14, 1960.

________. Waste Stabilization Lagoons. Proceedings of a Symposium at Kansas City, Missouri, August 1-5, 1960. Division of Water Supply and Pollution Control, Region VI, Kansas City, Missouri, 1961.

________. Problems in Financing Sewage Treatment Facilities. Division of Water Supply and Pollution Control. Washington, 1964.

U. S. Department of the Interior, Federal Water Pollution Control Administration. Manpower and Training Needs in Water Pollution Control. Report to the Congress of the United States, Document No. 49. 90th Congress, 1st Session, 1967.

________. Sewage Treatment Plant Construction Cost Index. Division of Construction Grants.

________. Sewer Construction Cost Index. Division of Construction Grants. U. S. Government Printing Office. Washington, D. C., 1964.

________. Sewage and Water Works Construction, 1965. Washington, 1966.

U. S. Department of Labor. Indexes of Output Per Man-Hour, Hourly Compensation, and Unit Labor Costs in the Manufacturing Sector, 1947-1966. Bureau of Labor Statistics. Washington. June 1967.

Water Pollution Federation. Design and Construction of Sanitary and Storm Sewers, WPCF Manual of Practice No. 9. Prepared by a Joint Committee of the Water Pollution Control Federation, 1960.

________. Sewage Treatment Plant Design, WPCF Manual of Practice No. 8. Prepared by a Joint Committee of WPCF and the American Society of Civil Engineers. Washington: Water Pollution Control Federation, 1957.

________. Uniform System of Accounts for Waterwater Utilities. Prepared by WPCF Committee on Sewage and Industrial Wastes Practice, Subcommittee on Sewage Works Finance. Washington: Water Pollution Control Federation, 1961.

INDUSTRIAL REQUIREMENTS
AND COST ESTIMATES

Volume II

Part II

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INTRODUCTION

Waste controls and wastewater cooling facilities having a current replacement value of from over $5 billion to more than $6 billion must be utilized to achieve by FY 1973 the level of industrial waste reduction and temperature control assumed to be necessary to provide adequate protection against water pollution. Roughly half of the value of the necessary investment is presently provided by industrial waste treatment and cooling plants in place, or by municipal facilities which treat industrial wastes. But an investment of from almost $2 billion to almost $3.5 billion will be required to overcome the accumulated deficiency in industrial waste treatment and cooling facilities that exists in 1968, another $.5 billion to $1 billion will be required to keep pace with industrial growth between 1968 and 1973. The annual cost of operating and maintaining the system is expected to rise from $550 million at the inadequate 1968 level of operations to over $1 billion, exclusive of depreciation, by 1973.

The costs indicated are those associated with assigned levels of efficiency: 85% removal of standard BOD and of settleable and suspended solids contents of waterborne industrial wastes and achievement of a 13° average temperature reduction. It must be recognized that the values have no application to specific situations - greater or lesser efficiencies may be required to maintain water quality standards at any point. The requirement is expressed in average terms. Similarly, attainment of the requirement is evaluated in terms of prevailing approaches and technology and average costs. There are many alternative methods of meeting the waste reduction and the cooling requirement. The combination of decisions regarding adoption of the alternatives will have a profound impact on realized costs.

The ultimate cost to industry and to the economy of providing a degree of waste treatment sufficient to maintain water quality standards for interstate waters will depend on the interweaving of a complex set of variables that includes (but is probably not limited to) industrial location, water use technology, regulatory policy, rate of increase in industrial output, the composition of industrial output, waste treatment technology, development of cooperative institutional arrangements, and the speed with which obsolete industrial plant is replaced.

The critical nature of industrial pollution control is indicated by the assessment of gross volume of industrial waste production presented in this report. While no national inventory of industrial waste sources has yet been assembled, it has been possible to gather reasonably reliable information regarding both the volume of industrial wastewater and of industrial production. Engineering studies of the waste handling requirements of a wide variety of industrial processes have produced data which permit waste-to-product ratios to be calculated for many processes and products. Application of these ratios to published estimates of output, then, provides a gross sizing of constituents of the industrial wasteload.

While the obvious weaknesses of an attempt to quantify the industrial waste problem on the basis of limited data must be recognized, it is apparent that industrial wastes are a much larger potential source of water pollution than are the wastes of the nation's municipal populations. Estimated production of standard BOD by industry is almost three times that of municipalities; production of suspended solids is between two and three times that of municipalities. In addition, polluting increases in temperature, alkalinity, acidity, color, metals, and toxicants in our nation's waters as a result of the wastes of industrial processes are significant and growing.

In evaluating this assessment of wasteloads and treatment costs, two factors must be kept in mind. First, the industrial waste problem is greater than a simple comparison with municipal wastes would indicate. The variety of pollutants other than heat, standard BOD, and suspended solids, the gaps in the data, the unreliability of the standard BOD test for non-human waste products - all suggest strongly that an assessment of industrial wasteload quantities made with the present state of information must, of necessity, be an under-evaluation. Second, technological improvements which advance the cost-effectiveness of waste treatment, opportunities for modification of production processes to reduce unit waste production, and cooperative waste handling procedures should be utilized fully to lessen costs, in order to offset the cost-increasing effects of industrial concentration and hard-to-treat wastes.

VOLUME OF INDUSTRIAL WASTES

Definition of treatment requirements and costs associated with the nation's production of industrial wastes has, as a preliminary condition, required an assessment of the volume and pollutional characteristics of industrial wastes. No such assessment has ever been made before. Evaluations of industrial wastes to this time have occurred in connection with localized problems.

In order to provide the required quantitative framework for this study, the FWPCA undertook to correlate the results of an extensive search of the technical literature of industrial wastewater characteristics with the data on industrial water use presented in The 1963 Census of Manufactures, "Water Use in Manufacturing." Efforts were bent to development of three pieces of information: (1) characteristic waste products of major water using industrial processes, (2) normal volume relationships for industrial processes between unit material outputs or inputs and pollutants, and (3) relationships between total output, total water use, and wastes for industrial sectors in the census year.

The investigation of wastewater characteristics produced a large number of estimates of characteristic kinds of waterborne wastes generated by specific industries. But though the list, presented in Table II-1, is extensive, only a few pollutants have been reported in meaningful detail.

Five-day biochemical oxygen demand (BOD_5) was reported most frequently. Other parameters for which considerable data are available are suspended solids, total solids, and pH (a measure of alkalinity or acidity).

The deficiency of data with regard to many industrial pollutants symptomizes a deficiency in the general approach to pollution control. There has been a tendency to view and evaluate all pollutants in terms of their analogy with sanitary wastes. Thus waste treatment efficiency is almost universally expressed in terms of percentage BOD removal, although it is recognized that, in the case of industrial pollutants, the effectiveness of control will often depend on removal of specific compounds that may or may not contribute to standard BOD measured in the waste stream.

The shift from qualitative analysis - identification of the kinds of materials found in various industrial wastewaters - to quantitative description involved enormous difficulties, due largely to data deficiencies. It was found that the concentrations of given pollutants per unit of product for any industry varied greatly from one plant to another. Lack of information regarding other pollutants required the analysis to be expressed largely in terms of standard BOD and suspended solids. Moreover, the census data on water use are in many cases inconsistent, incomplete, and inexact. These deficiencies appear to be due, in large part, to industry's limited accounting for water

TABLE II-1

CURRENTLY REPORTED WASTEWATER CHARACTERISTICS BY INDUSTRY GROUPS

SIC Code	201	202	203	204	206	208	22	26	281
Liquid Waste Characteristic	Meat Products	Dairies	Canned & Frozen Foods	Grain Mills	Sugar	Beverages	Textile Mill Products	Paper & Allied Products	Basic Chemicals
Unit Volume	X[1]	X	X	X	X	X	X	X	X
pH	X	X		X	X	X	X	X	X
Acidity					X	X	X		X
Alkalinity	X				X	X	X	X	X
Color							X	X	X
Odor							X		X
Total Solids	X	X		X	X	X	X	X	X
Suspended Solids	X	X	X	X	X	X	X	X	X
Temperature	X							X	X
BOD_5/BODultimate	X	X	X	X	X	X	X	X	X
COD				X		X			X
Oil & Grease	X	X			X		X	X	X
Detergents (Surfacants)							X	X	X
Chloride	X					X		X	X
Heavy Metals:									
Cadmium									X
Chromium							X		X
Copper							X		X
Iron									X
Lead									X
Manganese									X
Nickel									X
Zinc							X		X
Nitrogen:									
Ammonia	X				X		X	X	X
Nitrate							X		X
Nitrite							X		X
Organic	X	X			X			X	X
Total	X						X	X	X
Phosphorus									X
Phenols							X		X
Sulfide							X	X	X
Turbidity							X		X
Sulfate							X	X	X
Thiosulfate							X		X
Mercaptans								X	X
Lignins								X	
Sulfur								X	X
Phosphates								X	X
Potassium								X	X
Calcium								X	X
Polysaccharides								X	X
Tannin								X	
Sodium								X	X
Fluorides									X
Silica									X
Toxicity							X		X
Magnesium									
Ammonia									X
Cyanide									X
Thiocyanate									
Ferrous Iron									
Sulfite								X	
Aluminum									X

TABLE II-1

CURRENTLY REPORTED WASTEWATER CHARACTERISTICS BY INDUSTRY GROUPS (CONT'D.)

SIC Code	262	2871	2911	3111	331	3334	3717	3722
Liquid Waste Characteristic	Fibers Plastics & Rubbers	Fertilizer	Petro-leum Refining	Leather Tanning & Finishing	Steel Rolling & Finishing	Primary Aluminum	Motor Vehicles & Parts	Aircraft Engines & Parts
Unit Volume	X	X	X	X	X	X	X	X
pH	X	X	X	X	X	X	X	X
Acidity		X	X	X	X	X	X	X
Alkalinity			X	X	X		X	X
Color	X		X	X			X	X
Odor	X		X				X	X
Total Solids	X	X		X	X	X	X	X
Suspended Solids	X		X	X	X		X	X
Temperature	X	X			X		X	X
BOD_5/BODultimate	X		X	X	X		X	X
COD	X		X		X		X	X
Oil & Grease	X		X		X		X	X
Detergents (Surfacants)	X						X	X
Chloride	X		X	X	X		X	X
Heavy Metals:								
Cadmium							X	X
Chromium				X			X	X
Copper							X	X
Iron			X		X		X	X
Lead							X	X
Manganese			X				X	X
Nickel							X	X
Zinc							X	X
Nitrogen:								
Ammonia		X	X	X	X			
Nitrate								
Nitrite								
Organic			X	X				
Total		X		X				
Phosphorus		X						
Phenols	X		X		X		X	X
Sulfide			X	X	X			
Turbidity			X					
Sulfate	X		X	X				
Thiosulfate								
Mercaptans			X					
Lignins								
Sulfur								
Phosphates		X					X	X
Potassium			X					
Calcium			X					
Polysaccharides								
Tannin				X				
Sodium			X	X				
Fluorides		X	X		X	X		
Silica		X					X	X
Toxicity	X							
Magnesium			X					
Ammonia		X	X		X			
Cyanide					X		X	X
Thiocyanate					X			
Ferrous Iron					X			
Sulfite								
Aluminum								

as a raw material. Extension of the disclosure rule to water, where its relevance is doubtful, must bear a considerable responsibility for the weaknesses of the census of water use as an analytical tool.

While the weaknesses in precision of the assessment of waste volumes must be admitted, its utility can scarcely be questioned. The data - presented in Table II-2[1] - indicate that manufacturing is not, as has often been suggested, roughly equal in pollutional effect to municipal populations. It is, in fact, a far more significant source of pollutants, and probably of pollution, than is the nation's sewered population. In terms of gross quantities alone, prior to treatment manufacturing wastes have an estimated BOD more than three times that of all sewered municipalities and contain more than twice the suspended solids content of municipal wastes. Moreover, increasing per capita output, and degree of processing involved in that output, indicates that industrial waste volumes are growing at a much more rapid rate than are domestic waste volumes.

Perhaps more significant than the gross quantity of industrial waste is its concentration. A few industries - paper and allied products, the chemicals group, petroleum refining, sugar refining, primary metals - which are typically composed of a relatively few, relatively large plants, use most of the nation's industrial water and produce most of the nation's wastes. Wherever one of these big, high pollutant-producing plants is located, the potential for pollution is high. Because industries tend to be concentrated at points of demand or of raw material availability, and because industrial concentrations create or are attracted to concentrations of population, the environmental effects of such industries are magnified beyond the level that their gross production of pollutants would suggest.

The tendency to industrial concentration has a tremendous impact on the regional prevalence of industrial water pollutants. The great preponderance of American industrial water use, as measured by wastewater discharge, occurs in the northeast - the North Atlantic, Great Lakes, and Ohio River Drainage areas.[2] While volume of water discharge is in no sense a direct index of

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[1] *The data, as presented in the table, has been reworked to fit the broad industrial classifications utilized in this report. The original form of the table - to be found in National Industrial Waste Assessment, T. J. Powers, III, et. al. - is considerably more detailed, and organized in a fashion more amenable to conventional engineering use than is the material in this report, which is directed to the economic aspects rather than the engineering functions involved in pollution control.*

[2] *Throughout this discussion, the geographic frame of reference is the major drainage areas defined by the Water Resource Council. Data, however, are reported by Bureau of Census' "Industrial Water Use Regions." There are slight differences between the regional boundaries as defined*

TABLE II-2

ESTIMATED VOLUME OF INDUSTRIAL WASTES BEFORE TREATMENT, 1964[1]

Industry	Waste-water Volume (Billion Gallons)	Process Water Intake (Billion Gallons)	BOD_5 (Million Pounds)	Suspended Solids (Million Pounds)
Food & Kindred Products	690	260	4,300	6,600
Meat Products	99	52	640	640
Dairy Products	58	13	400	230
Canned & Frozen Food	87	51	1,200	600
Sugar Refining	220	110	1,400	5,000
All Other	220	43	670	110
Textile Mill Products	140	110	890	N. E.
Paper & Allied Products	1,900	1,300	5,900	3,000
Chemical & Allied Products	3,700	560	9,700	1,900
Petroleum & Coal	1,300	88	500	460
Rubber & Plastics	160	19	40	50
Primary Metals	4,300	1,000	480	4,700
Blast Furnaces & Steel Mills	3,600	870	160	4,300
All Other	740	130	320	430
Machinery	150	23	60	50
Electrical Machinery	91	28	70	20
Transportation Equipment	240	58	120	N. E.
All Other Manufacturing	450	190	390	930
All Manufacturing	13,100	3,700	22,000	18,000
For comparison:				
Sewered Population of U. S.	5,300[2]		7,300[3]	8,800[4]

[1] *Columns may not add, due to rounding*

[2] *120,000,000 persons x 120 gallons x 365 days*

[3] *120,000,000 persons x 1/6 pounds x 365 days*

[4] *120,000,000 persons x 0.2 pounds x 365 days*

pollutants produced by industry, it provides a good scaling of relative magnitude. It is clear, from reference to Table II-3 and Figure II-1, that industrial-originating pollution control requirements cluster overwhelmingly in the Northern United States, between the Mississippi River and the Atlantic Ocean.

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by the two agencies, the basis for the boundary being physical in the one case, political in the other. However, the combination of the Census' New England, Delaware and Hudson, and Chesapeake Bay regions accords very closely with the WRC's North Atlantic Region; the combination of the Cumberland and Ohio Water Use Regions corresponds well with the WRC Ohio Drainage Area; the Rio Grande plus the Texas-Gulf WRC regions are essentially the same as the Census' Western Gulf; the Missouri Region of the Census contains most of the Souris-Red-Rainy drainage area; and the two Great Lakes Industrial Water Use Regions are, together, much like the Great Lakes Drainage Area. It was found necessary, too, to add together the Great Basin and Colorado Basin to form a single analytical unit similar to the combination of the WRC's Upper Colorado, Lower Colorado, and Great Basin.

TABLE II-3

REGIONAL INCIDENCE OF INDUSTRIAL WASTE DISCHARGE, BY MAJOR INDUSTRIAL SECTORS, 1964

Industry	Percent of Discharge of Industry's Wastewater													
	Regionally Assignable Discharge	North-east	South-east	Great Lakes	Ohio	Ten-nessee	Upper Missis-sippi	Lower Missis-sippi	Missouri	Arkansas White-Red	Western Gulf	Colorado and Great	Pacific North-west1/	Cali-fornia2/
Meat Products	90.6	5.0	7.0	4.0	6.0	-	32.3	1.0	23.2	4.0	2.0	-	5.1	1.0
Dairy Products	64.0	10.3	3.4	22.4	3.4	-	7.2	-	5.2	-	-	-	5.2	6.9
Canned & Frozen Foods	68.8	3.4	18.4	8.0	-	-	3.4	-	-	-	-	-	14.9	20.7
Sugar Refining	56.7	6.3	-	-	-	-	-	36.4	10.4	-	-	-	-	3.6
All Other Food Products	95.1	21.0	4.3	15.5	7.1	.9	20.1	4.3	4.9	1.0	1.5	1.5	5.0	7.1
Textile Mill Products	98.4	31.1	55.6	1.5	.6	8.1	-	1.5	-	-	-	-	-	-
Paper & Allied Products	98.3	23.5	26.4	12.4	2.6	3.4	5.6	1.6	.1	3.4	1.4	-	46.7	1.2
Chemical & Allied Products	100.0	12.8	5.0	13.0	19.7	6.7	1.6	5.4	.4	1.3	32.0	.1	1.2	.8
Petroleum & Coal	97.6	26.8	.4	19.7	1.8	-	.8	9.1	1.6	1.1	25.5	.2	.2	10.5
Rubber & Plastics, n.e.c.	76.8	22.6	3.9	36.8	5.8	-	2.6	2.6	1.9	-	-	-	-	.6
Primary Metals	87.8	7.4	1.0	38.4	33.4	.5	2.3	-	.3	-	3.2	.2	.9	.2
Machinery	100.0	49.6	.7	16.8	8.1	-	22.8	-	-	-	.7	.7	-	.7
Electrical Machinery	99.0	35.2	3.3	19.8	28.6	1.1	6.6	-	1.1	1.1	-	-	-	2.2
Transportation Equipment	98.2	31.2	1.7	46.8	5.9	-	2.1	-	-	.8	-	-	1.7	8.0
All Other (plus Unassignable)	-	95.7	4.0	18.1	8.7	8.1	11.9	35.6	1.7	6.6	4.3	7.2	18.8	8.1
Total Industrial Discharge		19.9	6.9	23.4	18.2	2.4	3.5	3.7	1.2	1.4	12.2	.3	4.1	2.7

1/ *Includes Alaska*

2/ *Includes Hawaii*

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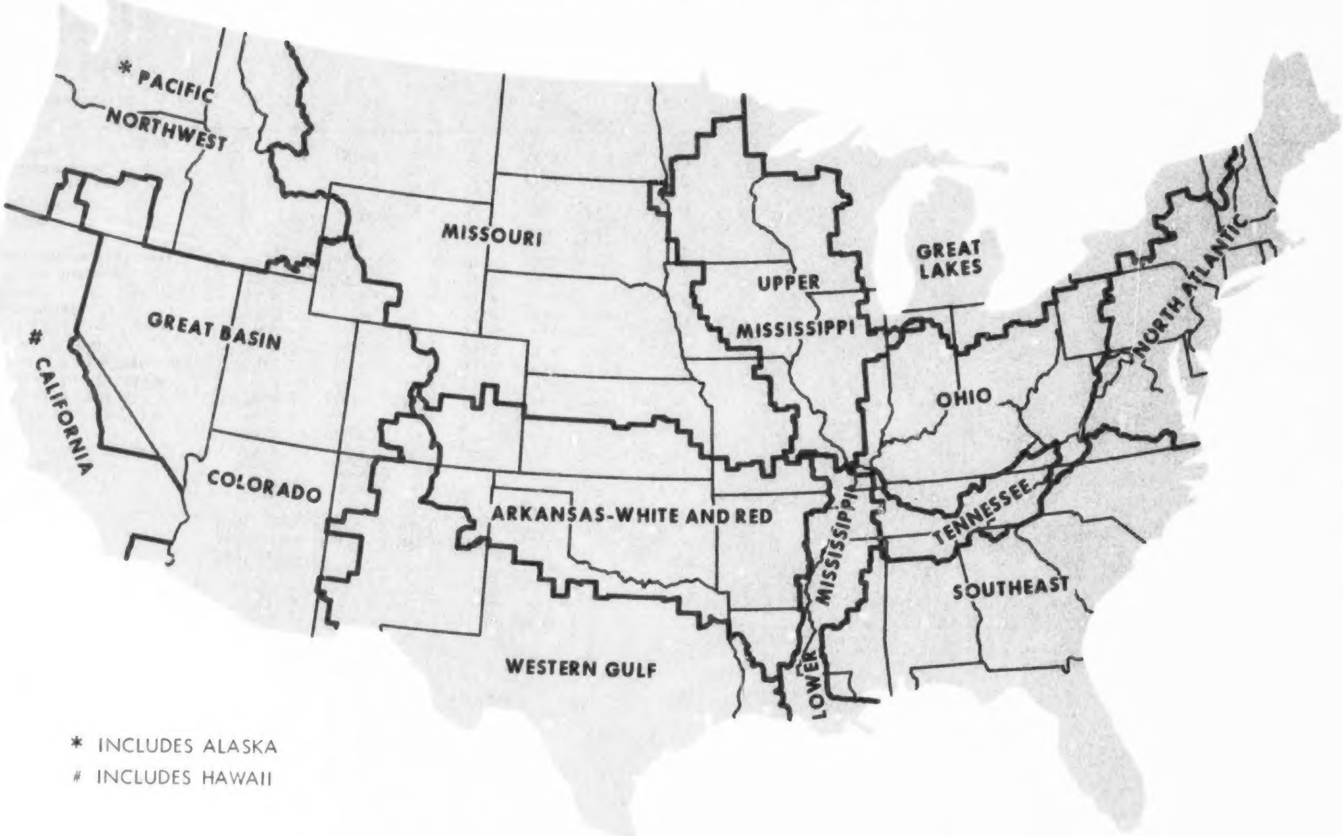
FIGURE II - 1
MAJOR DRAINAGE REGIONS, INDUSTRIAL DEFINITION


* PACIFIC NORTHWEST
MISSOURI
UPPER MISSISSIPPI
GREAT LAKES
NORTH ATLANTIC
# CALIFORNIA
GREAT BASIN
OHIO
COLORADO
ARKANSAS-WHITE AND RED
MISSISSIPPI
TENNESSEE
SOUTHEAST
WESTERN GULF
LOWER
* INCLUDES ALASKA
# INCLUDES HAWAII

METHODS AND PREVALENCE OF INDUSTRIAL WASTE CONTROL

VOLUME OF WASTE AND DEGREE OF TREATMENT

While there is no comprehensive inventory of industrial waste sources, the Census of Manufactures includes a survey of "Water Use in Manufacturing" that provides the raw data for a generalized assessment of industry's waste handling practices. A reported total of 13,157 billion gallons of wastewater was discharged in 1964, the date of the most recent survey, by manufacturing establishments that used 20 million gallons or more of water during that year.

Of the more than 13 trillion gallons of wastewater, some indeterminate part may be considered to have required treatment because of its pollutional characteristics. Total water intake of the surveyed establishments included 3,703 billion gallons of process water, all of which might be expected to require treatment prior to discharge, and 959 billion gallons of water for miscellaneous uses, of which at least the component utilized for sanitary services would require waste treatment. The largest category of water use, cooling water, accounted for 9,385 billion gallons of intake. Under many circumstances cooling water would not require treatment other than temperature stabilization. But where recycling involves the mixture of process and cooling waters or the diversion of used cooling waters to process application, then waters brought into a plant primarily for cooling would also be expected to require treatment in addition to temperature stabilization prior to discharge.

Industry, faced with the task of limiting the polluting effects of its wastewaters, may apply at least four techniques. The obvious approach is to add conventional waste treatment to the list of processes routinely performed by the manufacturing establishment. An alternative is to discharge liquid wastes to public sewers, delegating the task of treatment to municipal waste treatment plants. Effective protection of streams against polluting waste discharges may also be achieved by discharging wastewaters to the ground - either spreading them for irrigation on suitably sized tracts or inserting them into deep, sealed wells. Theoretically more attractive than any of the other three methods, a fourth approach to liquid waste handling is to modify processes to limit polluting discharges by segregating wastes, recycling waters, and reclaiming waste materials. In practice the methods are compatible and interchangeable with one another. It is not unusual for a manufacturing plant to use a combination of all four waste handling expedients.

INDUSTRY-OPERATED WASTE TREATMENT PLANTS

Although the Bureau of Census data indicate that the majority of manufacturing establishments depend on municipal waste treatment plants for satisfaction of their treatment requirements, the data also indicate that treatment facilities operated by industry treat a far greater volume of water. (Table II-4.) The industries which account for the major portion of manufacturers' water use are not generally suited, by reason of the volume or nature of their waste discharges, to use of municipal facilities.

The 10,600 manufacturing establishments that used 20 million gallons or more of water in 1964 operated some 3,700 reported waste treatment facilities, whose purpose and characteristic efficiency may be defined in a general fashion. The majority of plants did not report waste treatment. (Though a number of the same plants were connected to municipal facilities.)

The absence of a comprehensive inventory of industrial waste sources becomes crippling when one attempts to evaluate Bureau of Census data on liquid industrial wastes. It is obvious that a majority of American manufacturing plants do not treat their wastes - or did not in 1964. It is also clear that there is no straightforward relationship between number of treatment plants, level of waste discharge, and level of treated waste discharge that will allow an adequate judgment to be made about the relative adequacy of industrial waste treatment. (For example, there is no method to indicate what portion of the industrial waste stream receives: (1) primary treatment, (2) secondary treatment, (3) treatment beyond the secondary level, and/or (4) pretreatment that falls short of the primary level.)

An obvious problem with the data is the fact that the number of establishments providing definable levels of waste treatment is known to be less than the number of treatment facilities. A good portion of the primary treatment plants are operated in conjunction with secondary treatment plants; and there are instances in which several types of secondary waste treatment may be utilized for different portions of the waste stream of a single plant. Cumulative totals, then, do nothing to indicate the number of establishments that have attained a definite level of treatment efficiency.

Nor do the data do more than hint at the proportion of the waste stream that may be treated to a degree associated with primary or secondary standards. There are known to be instances in which regulatory authorities have insisted on treatment of sanitary wastes of a factory, while its industrial wastes are allowed to continue to be discharged untreated or partially treated; so that the proportionate presence of secondary waste treatment plants is an uncertain guide to the volume of wastewater receiving secondary treatment.

While the available data are only sufficient to provide hints as to its degree, they substantiate an already recognized deficiency in treatment of industrial wastes. Over half of the significantly sized manufacturing estab-

TABLE II-4

WASTE CONTROLLING TECHNIQUES, BY MAJOR INDUSTRIAL SECTORS, 1964

Industry	Waste-water, Billion Gallons	Treated Discharge to Surface Waters		Discharge to Sewers		Discharge to Ground	
		Billion Gallons	% Total	Billion Gallons	% Total	Billion Gallons	% Total
Food & Kindred Products	688	92	13.3	241	35.0	79	11.4
Textile Mill Products	135	20	14.8	44	32.5	5	3.7
Paper & Allied Products	1,947	689	35.4	81	4.1	11	.5
Chemical & Allied Products	3,662	568	15.5	153	4.1	38	1.0
Petroleum & Coal Products	1,317	941	71.4	31	2.3	5	.3
Rubber & Plastics	155	7	4.5	24	15.4	2	1.2
Primary Metals	4,312	1,147	26.6	157	3.6	20	.4
Machinery, except electrical	149	11	7.3	40	26.8	2	1.3
Electrical Machinery	91	7	7.6	49	53.8	3	3.2
Transportation Equipment	237	58	24.4	79	33.3	5	2.1
All Other	464	87	18.7	88	18.9	25	5.3
All Manufacturing	13,157	3,607	27.4	987	7.5	195	1.5

lishments in the nation reported no waste treatment in 1964, and the number of secondary waste treatment facilities reported by significant industrial plants amounted to less than 20% of the number of establishments.

Industry has, however, been adding to its inventory of waste treatment facilities - or at least to the volume of water passed through such facilities - at impressive rates. The level of in-plant treatment of industrial wastewaters has been climbing about three times as fast as the value of industrial output, with the trend apparent in every industrial sector. (Table II-5.)

TREATMENT OF INDUSTRIAL WASTES BY MUNICIPAL TREATMENT PLANTS

Discharge of industrial wastes to community sewers is probably the best established method of providing for industrial waste disposal. Table II-4 indicates that while only 7.5% of the wastewaters of establishments using over 20 million gallons of water a year are so disposed, sewering provides the principal waste handling expedient of seven of the 11 industrial sectors: food processing, textiles, rubber and plastics, machinery, electrical machinery, transportation equipment, and miscellaneous manufacturing.

Though industrial use of public sewer and waste treatment facilities is sanctioned by custom, there has been a relative decline in discharge of industrial wastes to public sewers during the 1960's. The recorded volume of such discharges dropped 10 billion gallons - 10% - between 1959 and 1964. At the same time, the total volume of discharged industrial wastewater increased 1.7 trillion gallons, or about 15%.

There are some good reasons for the decline in the use of public sewers for the discharge of industrial wastes. Unless these are evaluated, it is possible to misinterpret the evolving relationship between municipal treatment facilities and industrial waste discharges by projecting a decline in municipal treatment of industrial wastes; when, in fact, the trend to combined waste treatment is strong in many industries.

There has been a rapid increase in municipal waste treatment capabilities since World War II. Both the number of treatment plants and the average level of treatment have been rising steadily, the growth being most marked since the inauguration of Federal grants for construction of waste treatment plants. As recently as 1949, almost 40% of the nation's sewered communities and population did not have waste treatment provided to them. By 1962, less than 20% of the total number of sewered communities and 14% of the sewered population of the United States were without waste treatment - and well over half of the sewered communities and sewered population were provided with secondary waste treatment. (Table II-6.)

TABLE II-5

RELATIVE INCREASE IN OUTPUT AND TREATMENT OF LIQUID WASTES BY MAJOR INDUSTRIAL SECTORS, 1954-1964

Industry	Values Added, in Millions of Constant (1954) Dollars 1954	1964	Annual Rate of Increase	Treated Waste Discharge Billion Gallons 1954	1964	Annual Rate of Increase
Food & Kindred Products	13,398	18,513	3.3	38	158	15.3
Textile Mill Products	4,709	5,409	1.4	13	35	10.4
Paper & Allied Products	4,630	6,267	3.0	199	707	13.5
Chemical & Allied Products	9,547	15,364	4.9	338	580	5.6
Petroleum & Coal Products	2,241	3,031	3.0	458	1,006	8.2
Rubber & Plastics, n.e.c.	1,954	4,002	7.4	1	9	24.1
Primary Metals	9,772	13,436	3.2	270	1,178	15.9
Machinery, except electrical	12,333	15,870	2.6	3	12	14.9
Electrical Machinery	7,300	14,486	7.1	6	15	9.6
Transportation Equipment	13,428	19,241	3.7	9	24	10.3
All Other	37,720	49,769	2.8	53	101	6.7
All Manufacturing	117,032	165,388	3.5	1,388	3,825	10.7

TABLE II-6

GROWTH OF MUNICIPAL SEWER AND WASTE TREATMENT FACILITIES, 1949-1962

	1949	1957	1962
Number of Sewered Communities	N. A.	11,131	11,420
Sewered Communities Not Treating Wastes	3,718	3,165	2,249
Communities With Primary Waste Treatment Plants	3,019	2,730	2,672
Communities With Secondary Waste Treatment Plants	3,050	4,647	6,584
Estimated Population Served			
By Sewers Alone	28,067,000	21,918,000	14,687,000
By Primary Treatment	17,218,000	25,667,000	32,734,000
By Secondary Treatment	26,090,000	43,326,000	61,191,000

Source: *Glass, A. C. and Jenkins, K. H., Statistical Summary of 1962 Inventory of Municipal Waste Facilities in the United States, U. S. P. H. S., Washington, 1964.*

The addition of a waste treatment plant at the end of the sewer system interposes significant complications into the relationship between the manufacturer who uses the public sewer and the municipality which provides the sewer. The plant and its operation must be paid for; and the usual arrangement is to levy sewer charges based on volume and/or strength of wastes. Obviously such charges give the manufacturer a distinct incentive to utilize his water as fully as possible prior to discharge, and to segregate, for separate discharge, cooling water and other portions of his waste stream which do not require treatment.[3] Thus, a decline in volume of industrial waste discharges to public sewers is not incompatible with an increase in treatment of industrial wastes by municipal plants. Indeed, there is reason for supposing that this incentive to efficiency extends to waste production, and that the reductions achieved by many factories upon connection with municipal treatment systems apply to the strength as well as to the volume of discharges.

The distinction between municipal and industrial wastes becomes critical when the municipality begins to provide secondary waste treatment, as more than 3,500 communities have done since 1949. Factories whose wastewater discharges are characterized by inorganic materials or by presence of toxic materials that interfere with operation of biological systems are not suited to use of conventional secondary waste treatment. Extreme segregation - limiting the sewered discharge to sanitary and other organic wastes - or pretreatment are required by such manufacturing plants. The decline in manufacturers' use of public sewers between 1959 and 1964 occurred almost entirely in such industries. The primary metals and transportation equipment industries, together with metal fabricating components of miscellaneous manufacturing, reduced their discharges to public sewers by an estimated total of 126 billion gallons during the five-year period. (Table II-7.)

Another consideration acts to limit the use of municipal waste treatment facilities by manufacturers. The scale of water use in some industries is so great as to impose a completely different order of magnitude in the design of waste treatment works. The pulp and paper, chemical, petroleum refining, and primary metals industries account for only 27% of the number of manufacturing establishments using 20 million gallons of water or more per year, but account for more than 85% of their total water intake. Even when the wastes of such factories are suited to treatment in municipal facilities, the volume of water to be handled far exceeds the capacities of most municipal systems.

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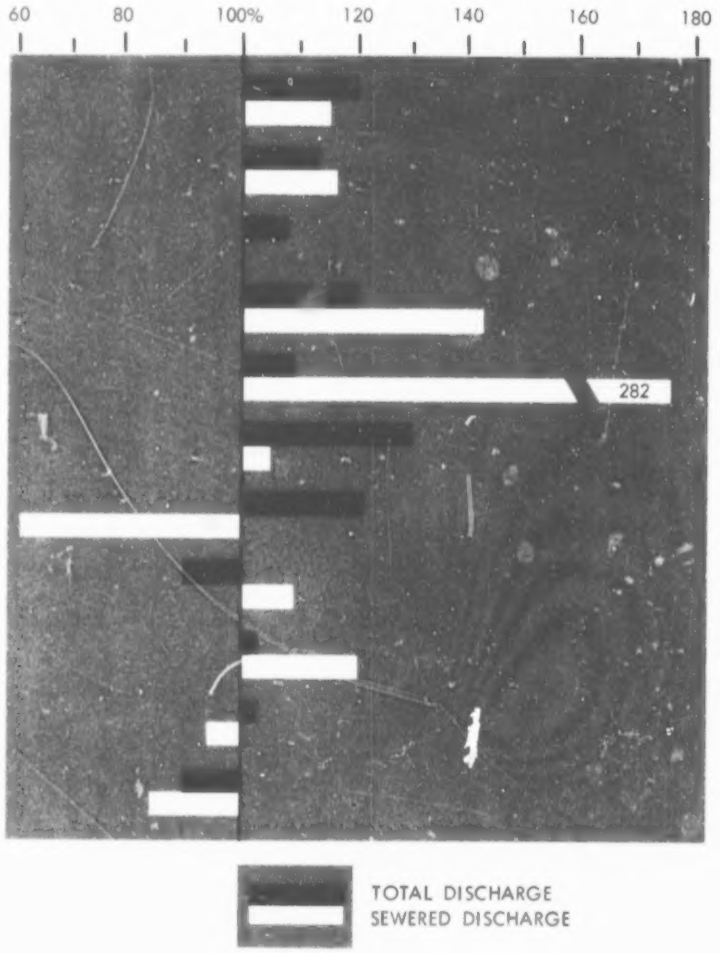
[3] *It should be noted that arrangements of this sort have, on occasions, involved real financial hardships for communities which sized waste treatment plants and apportioned user charges on the basis of an analysis of characteristic wastewater discharges, only to find that contributing industries were able to effectuate economies in water use and reductions in volume of waste discharges on a scale great enough to seriously upset the communities' financial plans.*

TABLE II-7
TOTAL DISCHARGE AND SEWERED DISCHARGE TRENDS 1959 - 1964 (1959 = 100%)

INDUSTRY	1964 AS A PERCENT OF 1959 TOTAL DISCHARGE	 SEWERED DISCHARGE
FOOD & KINDRED PRODUCTS	120	115
TEXTILE MILL PRODUCTS	113	116
PAPER & ALLIED PRODUCTS	107	100
CHEMICAL & ALLIED PRODUCTS	120	143
PETROLEUM & COAL PRODUCTS	109	282
RUBBER & PLASTICS, N.E.C.	130	104
PRIMARY METALS	121	60
MACHINERY, EXCEPT ELECTRICAL	90	108
ELECTRICAL MACHINERY	103	120
TRANSPORTATION EQUIPMENT	103	95
ALL OTHER MANUFACTURING	90	85
ALL MANUFACTURING	115	99
ALL MANUFACTURING, EXCLUDING PRIMARY METALS AND TRANSPORTATION EQUIPMENT	112	114



Such plants usually discharge wastes separately rather than into public sewers.

There are, however, indications that the situation is shifting with respect to cooperative municipal-industrial waste treatment plants that are scaled to handle organic wastes of the pulp and paper, chemical, and other large water using industries. In Bound Brook, New Jersey, a chemical plant treats municipal wastes, reversing the usual relationship between factory and community. In Kalamazoo, Michigan, three good sized paper mills and a chemical plant use a modern municipal sewage treatment plant. Metropolitan Chicago and Metropolitan Seattle have adopted ambitious programs to provide a high level of treatment for all liquid wastes - whether of domestic, commercial, or industrial origin - that occur within extended areas of jurisdiction. It would appear that technology is overcoming the lag that excluded large industrial waste sources from municipal treatment plants in the past; and that modern engineering competence is extending to the construction of efficient and very large treatment plants that are designed to handle wastes from a variety of sources. Since the trend, if apparent, is of recent origin, it is not reflected in the 1963 Census of Manufactures. Its nature and its effect on financial requirements of municipalities and industries probably cannot be evaluated prior to the appearance of the 1968 census of water use in manufactures. The possible impact on municipal waste treatment requirements of a large scale shift to joint treatment by the chemical, oil refining, or pulp and paper industries might be huge. Certainly regional dislocations would occur. Projections of joint treatment presented in Part I assumed consistent industry practice, so do not reflect the possibility of a change of this nature.

It would seem, from review of available information, that the availability of Federal construction grants may have promoted the use of combined municipal and industrial waste treatment facilities. The grants, for construction of interceptor sewers and waste treatment plants, are made only to public bodies; and their potential availability makes a pronounced difference among the cost variables that plant management must consider in coming to a solution of its waste treatment problem. If his wastes are to be treated in a municipal plant, the manufacturer, in effect, can secure Federal financing of a varying but substantial portion of his construction costs. The economies of scale resulting from construction and operation of larger plants, and the ability to delegate problems of operation to waste treatment specialists also argue for the cooperative method in providing for industrial waste treatment needs.

The practical result is that a number of communities - at the instance of local industries - are replacing existing treatment facilities in order to accommodate a larger portion of the total wasteload that is produced by factories, with the cost of the construction shared by community, industry, and Federal Government. (The effects are sometimes surprising. Two of the largest municipal waste treatment plants in the nation are operated by the tiny community of Monsanto, Illinois, and by little Nampa, Idaho. In each case, plant size and operating characteristics are dictated by the need of a local factory, a chemical plant in the one situation and a group of food processors in the other.)[4]

GROUND DISPOSAL OF LIQUID INDUSTRIAL WASTES

Discharge of liquid industrial wastes to the ground is a rather specialized technique of waste treatment that is of interest because of the rapid growth in its use, the high degree of protection of stream quality that it may afford, and its value as an example of the development of effective, low cost waste treatment practices. Use of the method is limited by availability of safe and suitable sites and by climatic conditions, however.

Table II-4 indicates that while ground discharge is used in disposal of little more than one percent of the total industrial waste flow, the technique has attained particular relevance in the handling of food processing wastes. The reasons for the association are easily understandable. Food processing tends to be a non-urban occupation, with plants located in food-producing areas. In many cases processing plants are located among the fields that provide raw materials. This circumstance provides many opportunities to utilize the liquid wastes of food processing - after very limited treatment such as solids removal - for irrigation, without incurring serious transmission costs. When such conditions exist, it is usually considerably less costly to use spent process water for irrigation than to treat it. The method makes for effective and economic use of water, while often providing a higher degree of stream protection than some forms of advanced waste treatment.

Distinctly different in concept from use of industrial wastes for irrigation is deep well disposal of such liquids. This method has been employed extensively for at least a decade in oil drilling to dispose of the great volume of brackish water brought up in petroleum production, and has been adopted by industries that deal with radioactive or toxic materials which normally cannot be released to the environment. Deep well injection seems particularly suitable for such liquid waste materials; and is often less costly than other waste controlling procedures. Its use is being extended to elements of the steel, chemical, and other industries. Technical difficulties, potential for groundwater contamination, and streamflow depletion all indicate, however, that deep well disposal must necessarily be considered a very specialized and limited waste handling method.

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[4] *Because no effort has been made to document and categorize the industrial wastes and waste treatment situation beyond the gross sizing approach attempted in this report, there is no comprehensive listing of relative use of public and in-house treatment methods by industry. A guide to the increasing prevalence of municipal treatment of wastes of industrial origin, however, is the fact that nine out of 10 applications by municipalities for Federal demonstration grants during the first six months of 1967 centered upon development of methods to handle industrial wastes.*

There is a definite pattern to the geography of ground disposal of wastes. Use of the method is pronounced in the far west, particularly in the arid regions of the Southwest and California, where irrigated agriculture underpins the economic base, and where water is in short supply. Conversely, ground disposal is least used in humid regions: New England, the Great Lakes area, the Ohio River Basin, the lower Mississippi area, and the western Gulf area. Acceptance of one form or another of ground disposal for liquid industrial wastes seems to be growing in most regions, and at rates well above those achieved by alternate methods of disposal. (Table II-8.)

TECHNOLOGICAL ADVANCE AS AN INDUSTRIAL WASTE CONTROL MEASURE

While in-plant waste treatment, use of public utility sewers, and ground disposal are generally recognized to be legitimate and effective methods of controlling industrial wastes, their combined effect in reducing the strength of industrial waste discharges may be less than that occurring as a result of process changes and advances in water use technology.

It is difficult to evaluate the waste-reducing effect of technological shifts, or to predict their influence on cost. It is true, too, that improved technology does not always act to limit waterborne wastes.[5] But, in the main, greater efficiency means reduction in waste relative to product; and such reductions extend to liquid wastes.

Waste reductions that come from process changes may involve not percentages but orders of magnitude. The most often cited example occurs in the pulp and paper industry, where the production of a ton of wood pulp by the older sulfite process results in 20 to 40 times the waste strength of a similar amount of pulp produced by the now dominant sulfate process. Since about 1940, most of the expansion that has occurred in the pulp and paper industry has taken the form of growth of sulfate production. As a result, pulp output has increased roughly two and a half times as fast as have wastes of pulp manufac-

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[5] *For example, fruit and vegetable processors today produce many times the unit wasteloads of their predecessors of a couple of decades ago as a result of automated materials handling procedures, the use of water as a transmission medium, the replacement of mechanical peeling with liquid caustic or steam peeling agents, and blanching procedures in freezing. Similarly, waste volumes in steel production have risen with increased processing, while the technology that allows use of lower grade ores throughout the metals industries is, by definition, high in relative unit wastes.*

TABLE II-8

TREND OF GROUND DISPOSAL IN INDUSTRIAL LIQUID WASTE HANDLING, 1959-1964

Major Drainage Basins	Total Industrial Waste Discharge to Ground (Billion Gallons)		Annual Rate of Increase in Ground Disposal	Percent of Regional Industrial Wastes Discharged to Ground	
	1959	1964		1959	1964
North Atlantic	22	29	5.7	1.0	1.2
Southeast	7	12	11.3	1.2	1.3
Great Lakes	14	17	3.9	.5	.5
Tennessee	1	10	69.2	.4	2.4
Ohio	13	15	2.9	.6	.6
Upper Mississippi	7	6	- 3.0	1.7	1.2
Lower Mississippi	1	3	25.0	.3	.5
Missouri	1	2	14.9	.9	1.5
Arkansas-White-Red	2	3	8.5	1.7	1.7
Western Gulf	3	2	- 8.5	.2	.1
Colorado-Great	2	3	8.5	4.9	6.7
California	13	19	7.9	4.9	6.0
Pacific Northwest	10	20	14.9	2.5	3.7
U. S.	98	195	14.7	.9	1.5

Source: Adapted from 1963 Census of Manufactures, "Water Use in Manufacturing".

ture. To put the matter in another perspective, if all pulp now produced by the sulfate process were being produced with sulfite pulping, BOD of the pulp and paper industry at current production levels would exceed 20 trillion pounds per year - or just about as much as is now produced by all manufacturing. (Figure II-2.)

Another example of the effect of technological improvement on production of pollutants can be found in the electrical power industry which has constantly reduced the amount of heat required to generate a given amount of thermally-produced power. The lower heat requirement - and that requirement has been declining steadily for over 40 years - means less wasting of heat to cooling water, thus proportionately less discharge of heated cooling waters. The average plant in 1965 is as efficient as was the best plant in 1945, two and a half times as efficient as the average plant of 1925. By using heat more effectively, the electrical power industry has achieved the same results in reducing heat loads to streams that it might have obtained from widespread installation of cooling towers and cooling ponds. (Figure II-3.)

Numerous examples of process changes that are more effective than treatment in reducing wastes might be considered - substitution of reclaimable pickling liquors for sulphuric acid by the steel and metal fabricating industries, complete recycling of process waters in the beet sugar refining industry, and use of solid waste material of various sorts as cattle feed by food processors. A number of such opportunities and trends are examined in profiles of specific industries, which are being published separately in Volume III of this report.

These discussions tend to indicate that improved technology does not ordinarily take the form of a major alteration in process, such as the shift from sulfite to sulfate pulping; it is more apt to involve a number of minor shifts in practice, a tightening of operations, or attention to engineering aspects of use of water as an industrial raw material. There are, in general, three considerations that lead the manufacturer to make the necessary investments and procedural changes to achieve such efficiencies:

(1) Water shortages, or increases in the price of water, constitute constraints on production or limit unit profitability. Water shortage is a general condition in much of the western U. S., and intermittent droughts or increased demands on a water system have created similar localized conditions throughout the nation.

(2) Opportunities to reclaim materials, and thus to increase volume of production with a constant raw material input, are improved with control of water, or reuse of water in the same or sequential process.

FIGURE II - 2

COMPARATIVE INDEX OF ANNUAL WOOD PULP PRODUCTION AND VOLUME OF PULPING WASTES, 1920 - 1960 (1920 = 100)

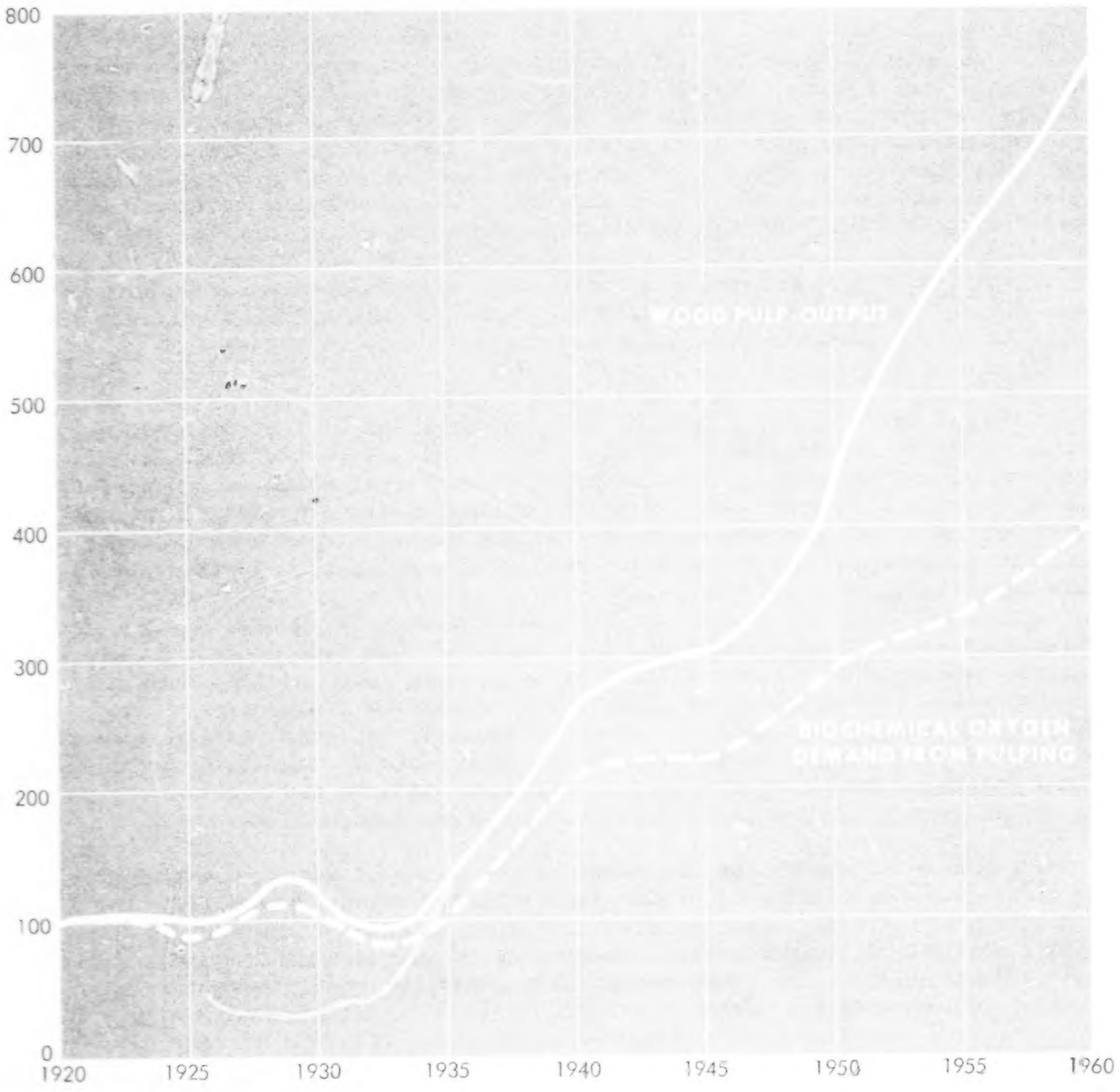
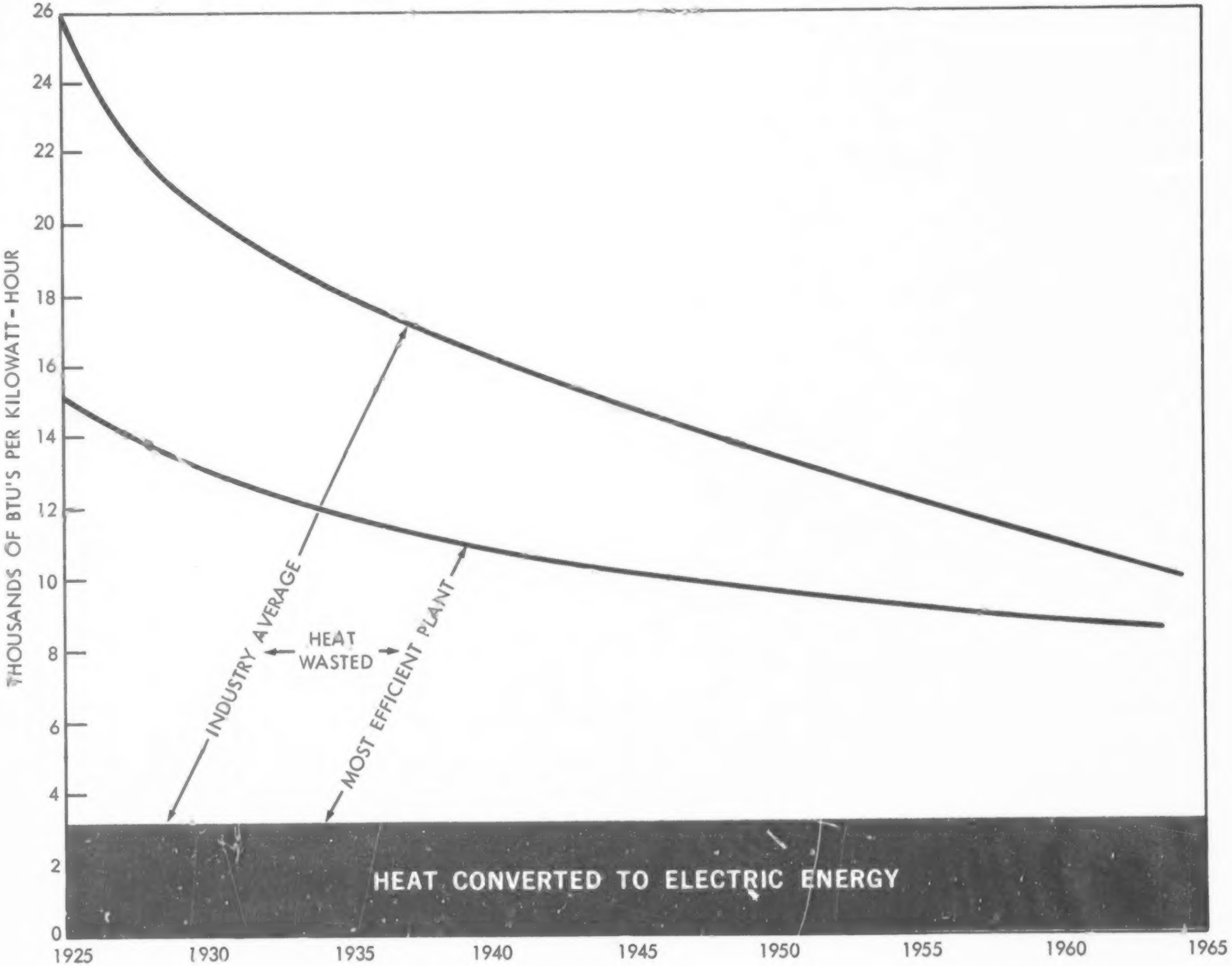


FIGURE II - 3

DECLINE IN HEAT WASTED IN STEAM-ELECTRIC POWER PRODUCTION



(3) Increasingly stringent enforcement of pollution control regulations has made it necessary for more and more establishments to provide waste treatment, either in-house or through available municipal works. In either case, limiting hydraulic loadings by segregation of waste streams and by reducing water use lessens required treatment plant capacity, and the consequent cost of waste treatment.

There is an indication that reduction in volume of wastewater is often accompanied by a reduction in the volume of pollutants discharged. While concentrations of pollutants might, in the normal order of things, be expected to rise in direct proportion to the decline in the volume of the carrying liquid, this is simply not the case for industry as a whole. The reason is that operating practices - "good housekeeping" - have a high degree of influence on the volume of wastes produced in a factory; and when hydraulic controls are tightened there is a corollary reduction in materials losses. In addition to this influence on waste volume, there are direct reductions attributable to engineering improvements specifically aimed at materials reclamation.

Some indication in quantitative terms of the magnitude of changes in the efficiency of water use is provided by the data from the Census of Water Use in Manufactures that is summarized in Table II-9. Two trends are immediately apparent. First, less water, including recycled water, is being used per dollar of value added by manufacture than in the past. Second, water is being used more intensively. The second trend is not surprising. It has long been recognized that there is a tendency to increased water reuse in manufacturing processes. Thus, total water use in 1964 of 30.6 trillion gallons was derived from an intake of 14.1 trillion gallons, indicating an average recirculation ratio for all manufacturing establishments of 2.2 to 1. In comparison, the reported 1954 intake of 11.6 trillion gallons was used an average of 1.8 times, providing a use equivalence of 21 trillion gallons. The 51% increase in values added by manufacture between 1954 and 1964 was achieved with only a 22% increase in water intake, in good part because of a 20% increase in the recirculation ratio.

The importance of "good housekeeping", careful water use controls, and improved process engineering becomes apparent when the relative increase in water use within the plant (i.e., including recirculation) is compared to the increase in value of physical output. Total water use in most industrial sectors increased at a far lower rate than did values added. Not only did the typical industrial plant of 1964 take in less water than it did in 1954, it used less water for each dollar's worth of output.

The relative significance of reuse of water and more efficient application of water per unit of product is made clearer by reference to Table II-10. The table describes the relationship between increased output and increased water use, dividing the index of growth of values added for the ten-year period 1954 to 1964 by the index of growth of water use, to express relative unit

TABLE II-9

RELATIVE CHANGE IN OUTPUT, WATER USE, AND WASTEWATER DISCHARGE, BY MAJOR INDUSTRIAL SECTORS

Industry	1964 as a Percent of 1954		
	Values Added in Constant Dollars	Total Water Use, Including Recirculation	Water Discharge
Food & Kindred Products	134	97	125
Textile Mill Products	137	147	92
Paper & Allied Products	162	142	120
Chemical & Allied Products	224	176	144
Rubber & Plastics, n.e.c.	203	160	125
Petroleum & Coal Products	138	148	116
Primary Metals	141	117	117
Machinery	160	128	128
(Machinery, other than Electrical)	N. A.	(195)	(117)
(Electrical Machinery)	N. A.	(205)	(101)
Transportation Equipment	156	204	110
All Other	144	86	83
All Manufacturing	151	145	122

TABLE II-10

RELATIVE INCREASE IN WATER USE EFFICIENCY AND IN WATER REUSE, BY MAJOR INDUSTRIAL SECTORS

Industry	Coefficients of Efficiency	
	Index of Increase in Value Added Per Unit Water Application	Index of Increase in Value Added Per Unit Water Intake
Food & Kindred Products	138	107
Textile Mill Products	93	149
Paper & Allied Products	114	135
Chemical & Allied Products	127	156
Rubber & Plastics, n.e.c.	127	162
Petroleum & Coal Products	93	119
Primary Metals	121	121
Machinery	125	125
Transportation Equipment	76	142
All Other	167	173
All Manufacturing	104	124

efficiency of a volume of water, and by the index of growth of water discharge, to express relative effect of recycling. It is apparent that in many industries efficient use, in terms of volume of water applied per unit of product, was almost as significant in reducing water intake as was recycling.[6]

While no general principles may be offered to quantify the potential effect of technological modifications on industrial waste treatment requirements and costs, there is adequate documentation to indicate that production technology may have enormous impacts. For example, a study of "The Economics of Poor Housekeeping in the Meat-Packing Industry"[7] conducted by W. J. Fullen and K. V. Hill revealed that the industry - based on an investigation of 28 plants - produced an average standard BOD concentration of 14.7 pounds per 1,000 pounds liveweight of animals slaughtered, with individual plant concentrations ranging from 6.5 pounds to 23.5 pounds per 1,000 pound animal. The difference between the high and the low BOD loads (17 pounds) could very well be viewed as equivalent to waste treatment efficiency of almost 73%.

There are other dramatic examples. The major drop in unit waste production in the papermaking industry that has occurred with the transition to the sulfate pulping process has been cited, but should not be construed to have ended the processing opportunities to reduce wastes that are available to the industry. For example, while an efficient integrated kraft plant can produce a ton of paperboard with a waste production of 45 pounds of BOD (including the wastes of pulping), two Willamette Valley (Oregon) producers have lowered waste production to nine or 10 pounds of BOD per ton of paperboard through use of tight process controls and the recycling of evaporator condensates. Very simple management techniques can have major impacts on waste production. For example, a pulp and paper plant operated by Crown-Zellerbach Corporation schedules production of low grade, high-yield products during summer low flows to obtain a 70% reduction in strength of final effluent - from 29 pounds of BOD per ton of production to nine pounds per ton - without performing treatment additional to that normally provided.

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[6] *For manufacturing as a whole, the increase in values added and in water use had almost a one-to-one relationship. This may be traced in large measure, however, to material shifts in physical output that occurred in several industrial sectors. In the textile industries, for example, the period 1954-1964 was marked by pronounced movement away from cotton and wool, and into synthetic materials. In the case of transportation equipment, production of jet aircraft accounted for a very significant portion of the total increase in values added, so that the technological and product mix that went into the determination of the water use to values added relationships in 1964 was quite different from that of 1954.*

[7] *ASCE, Journal of the Sanitary Engineering Division, Volume 39, No. 4.*

Some waste reducing effects of technological improvements can be foreseen for any industry, since their adoption is a function of the rate of capital investment in the industry. Figure II-4 depicts graphically the unit waste production and wastewater discharge associated with a group of industrial processes in terms of levels of technology. The figures, adapted from the Industrial Waste Profiles, indicate the effects of three levels of current technology on waste production in the affected industries. It is clear, for example, that as old plants are phased out or modernized and new plants are built, waste reduction will become an increasingly critical problem in the steel industry - where the new technology incorporates both a higher degree of processing and a lower grade of raw material - but less of a problem in some other industries.

The impact of technological advances on total waste production has occurred largely without reference to their benefits in terms of pollution control. Advanced technological processes have been adopted because they were more profitable, and resulting waste reduction results have been incidental benefits. Development of specific waste-limiting process modifications as an end in itself remains to be realized.

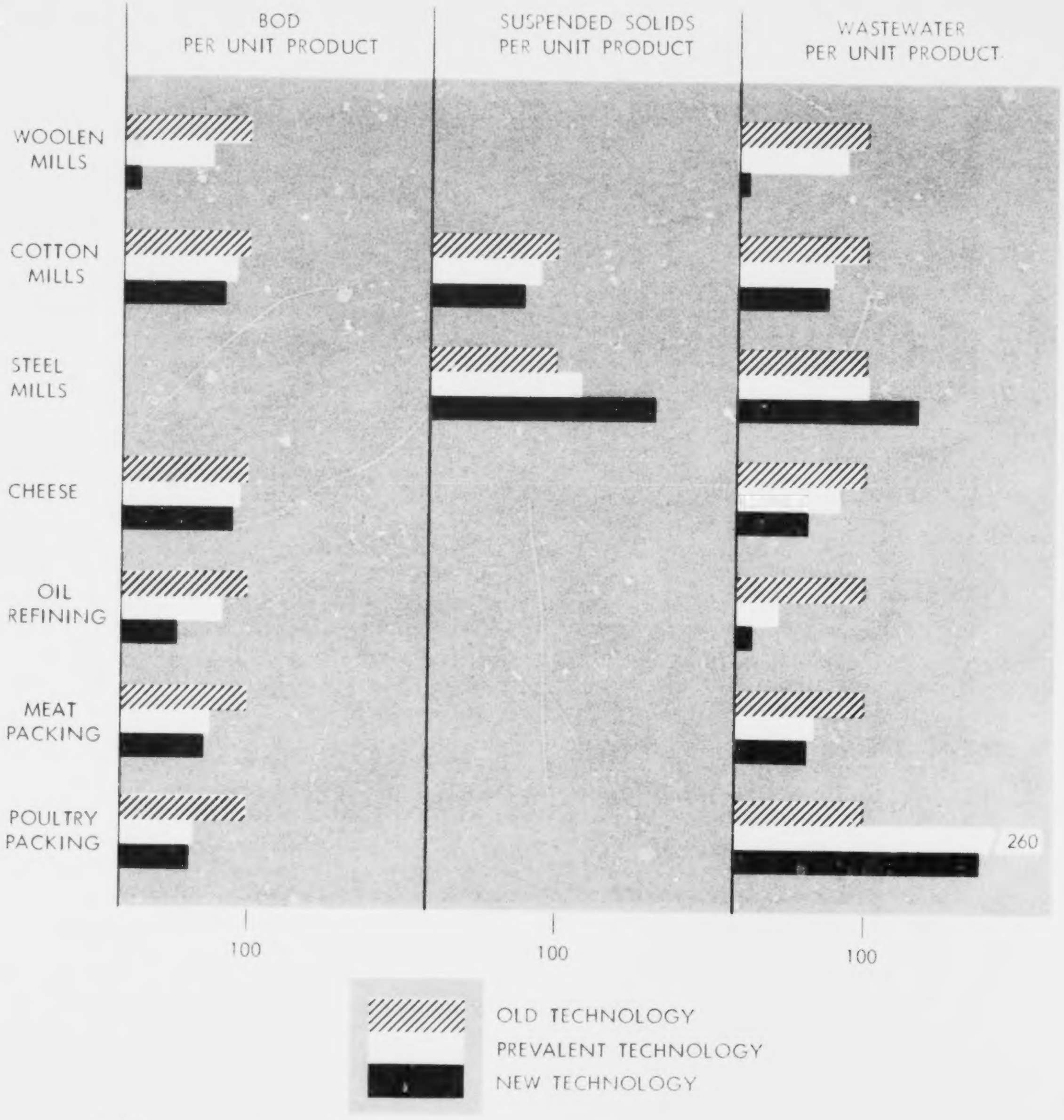
More rapid utilization of the prospective waste reducing efficiency of process modification would seem to be a likely result of the new element in the profit equation introduced by the increasing attention given to environmental protection and pollution control. The manufacturer who considers waste control to be an integral portion of the production process will attempt to design and modify his plant in order to obtain the required reduction efficiencies at lowest cost - including the combined cost of in-plant reduction of loadings and of final treatment. Complete control of wastes within the plant is not an unrealistic goal in some industries. In most cases, however, such efficiencies are not attainable. In all cases, steps taken by plant management to reduce the volume of wastewater or the strength of waste loadings lessen the cost of constructing and operating waste treatment facilities. Thus, the engineering of an in-plant waste control system, as opposed to the addition of a waste treatment plant to an otherwise unrelated production system, offers the prospect of optimum control of all waste-associated costs of production. (Figure II-5.)

The effectiveness of process modifications in reducing wastes is given some quantitative dimensions in Table II-11, provided by Mr. Blair Bower, an associate of Resources for the Future. While the unit wasteload quantities in this table may differ in detail from those quoted elsewhere in this report, the concept of major waste reduction from process or other in-house modifications is shown clearly.

If it is assumed that, on the average, newer technology generates less waste per production unit, it also must be recognized that the adoption of such technology probably will take place because of its overall effect on profits rather than its contribution to pollution abatement. The newer technology's

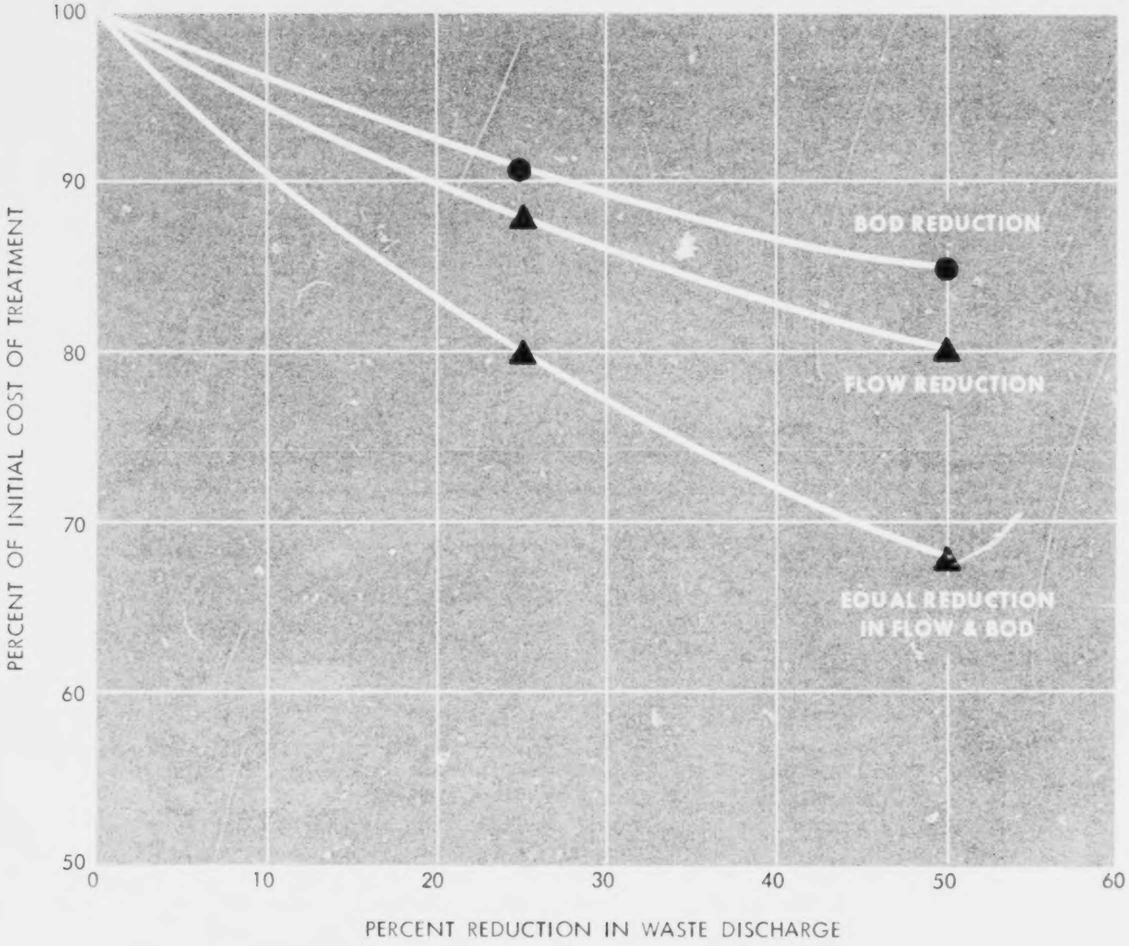
FIGURE II - 4

*INDEX OF UNIT WASTEWATER AND POLLUTANT CONCENTRATIONS ASSOCIATED WITH CURRENT PRODUCTION TECHNOLOGIES (OLD TECHNOLOGY = 100)



* Source: Industrial Waste Profiles.

FIGURE II – 5
EFFECT OF REDUCTION IN INITIAL WASTE LOADING
ON TREATMENT PLANT COST



Adopted From: Petroleum Refining Industry Wastewater Profile (Roy F. Weston)

TABLE II-11

COEFFICIENTS OF LIQUID WASTES GENERATED, BY INDUSTRY CATEGORY

Industry Category	Wasteload Generated, in Pounds (#) of BOD_5					Source(s)
	Present	Future: With No External Stimulus		Future: With External Stimulus		
		Coefficient	Assumptions	Coefficient	Assumptions	
Meat-Packing	12# BOD/1,000# of live weight	12#	No reason to increase; product mix not adverse	10#	Better utilization likely	Eckenfelder
Fluid Milk	1.2# BOD/1,000# intake	1.2#	No apparent reasons for change	1.0#	Better housekeeping possible	Eckenfelder
Canned and Frozen Foods	30# BOD/ton of raw product processed	30#	Predominance of vegetables in area; product mix not adverse	20#	Improved raw materials; better internal utilization	Bower
Cane Sugar	4# BOD/ton of product	4#	Relatively straightforward production process; essentially one product	2#	Assume changes possible as in beet sugar industry	Gurnham
Beet Sugar	2# BOD/ton of product	2#	Same as above	1#	Same as above	Gurnham
Distilled Spirits	0.5# BOD/bushel of grain processed	0.5#	No change foreseeable	0.5#	No change foreseeable	Gurnham
Cotton Finishing	50# BOD/1,000 linear yards	70#	Product proliferation, coatings, etc.	30#	Process modification possible	Gurnham, Bonem
Synthetic Textiles Finishing	20# BOD/1,000 linear yards	25#	Product proliferation	10#	Process modification	Gurnham, Bower
Paper Mills	80# BOD/ton of product	100#	More emphasis on fire and specialty papers	40#	Process modification; materials recovery	Gurnham, Bower
Paperboard Mills	50# BOD/ton of product	60#	Proliferation of coatings, colored product	25#	Process modification, materials recovery	Gurnham, Bower
Paper Coating and Glazing	30# BOD/ton processed	50#	Product proliferation	20#	Process modification	Gurnham, Bower
Paper Containers	30# BOD/ton processed	50#	Product proliferation, coatings	20#	Process modification	Gurnham, Bower
Petroleum Refining	100# BOD/barrel of crude processed	110#	Greater jet fuel, gasoline per barrel of crude; increase in average complexity	75#	Process modification; better housekeeping	Stormont
Leather Tanning and Finishing	150# BOD/1,000 square feet tanned	150#	No change foreseeable	100#	Better utilization; no adverse product mix	Gurnham, Bonem

effect in reducing unit wasteloads is reduced to a considerable extent by the persistence of profitable manufacturing plants still using outmoded processes and procedures. New plants generally produce less wastes than old plants and are more efficient in their use of water. Therefore, they are better able to deal with the financial and engineering problems of waste treatment. But many old plants continue to operate. The pulp and paper industry again provides an example. In 1920, nine tons of sulfite pulp were produced for every ton of sulfate pulp; today, five tons of sulfate pulp are produced for every ton of sulfite pulp. No new sulfite mill has been built for over 10 years and at least two have been closed; yet sulfite pulp production amounts to twice what it was in 1920. Apparently many old plants are sufficiently profitable to remain in operation; they continue to expand their output; and it is not always practical to modify them to incorporate newer, waste-reducing technology.

It is important to recognize that technological improvements have had the effect of slowing the rate of growth of pollution by providing constantly greater efficiency. But the average age of the American manufacturing establishment is about 20 years - among the oldest among highly industrialized nations - and older, high-pollution technology will not be phased out so long as it is profitable.

COST STANDARDS AND INVESTMENT REQUIREMENTS

ANALYSIS OF UNIT COSTS

There are neither general rules with regard to the cost of treating a given amount of the waste of a given industrial process to a desired effluent standard, nor sufficient information to formulate such rules. Obviously, the area is one in which a great deal of data accumulation and statistical analysis are required. Because of prevailing deficiencies in information exchange, it is not unusual to find that professionals who specialize in industrial waste treatment systems disagree with respect to cost standards.

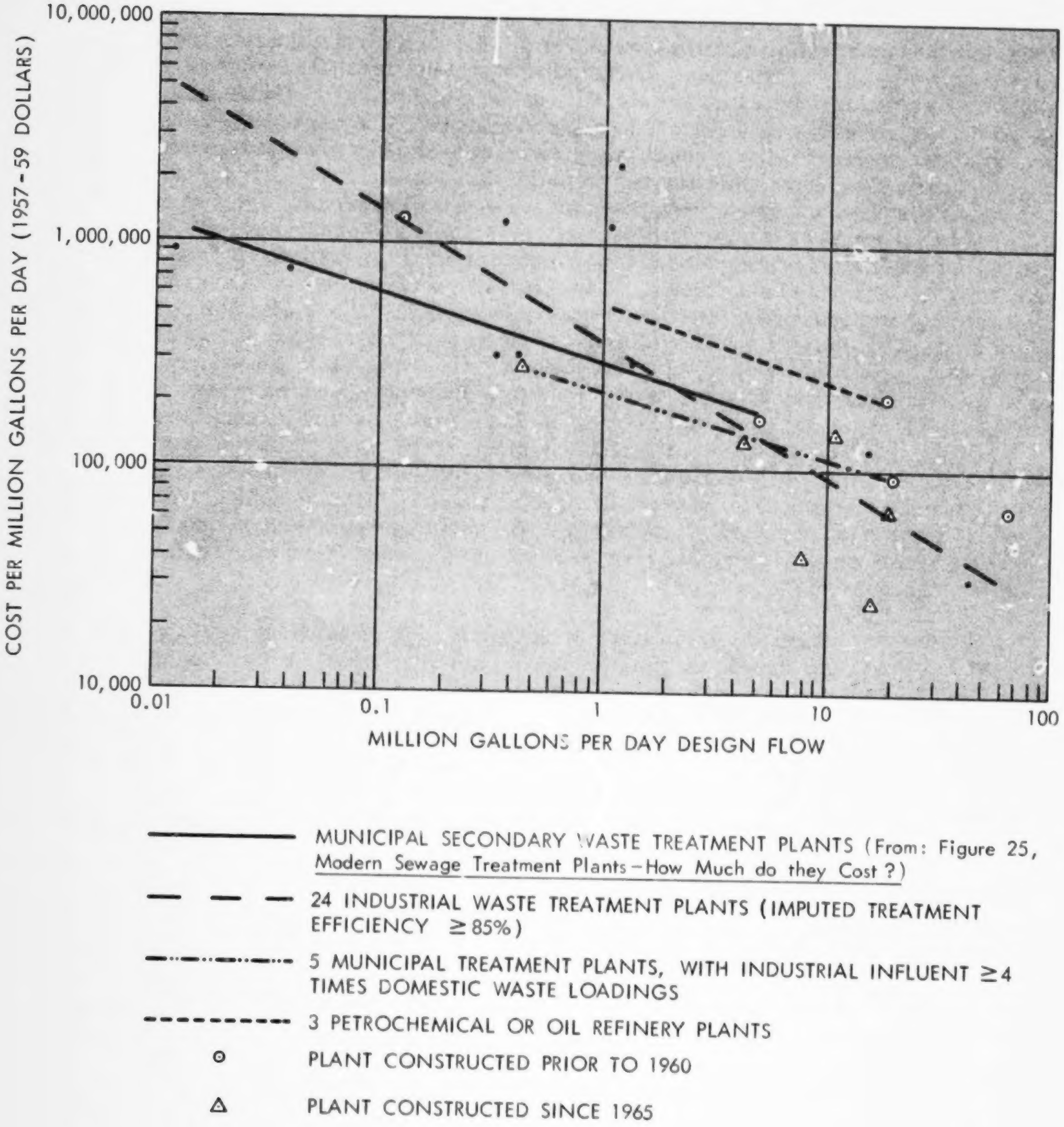
In order to resolve some of the uncertainties with regard to cost and to provide a basis for further study, a statistical analysis of industrial waste treatment plant construction costs was undertaken. Published articles, FWPCA Regional Office files, and applications submitted to obtain Federal demonstration grants provided a very limited number of cases which contained sufficient information about plant cost, waste reduction efficiency (at least 85% BOD_5 removal required for inclusion), and design flow to be incorporated into the sample. In the absence of adequate samples to review costs for separate industrial sectors, the analysis considered the entire group of industrial waste treatment plants to compose a single sample which was analyzed for correlation of two parameters, hydraulic loading and construction costs. The analysis, presented graphically in Figure II-6, suggests some interesting considerations.

(1) Industrial waste treatment plants are probably less costly - per gallon of water treated, per pound of BOD, or per pound of solids removed - to construct than are municipal plants. This is not surprising. The industrial operation is subject to much greater control. Flows can be equalized, unlike municipal wastewater which operates under severely shifting influent patterns through the day. Waste concentrations can often be altered through mixing and dilution to achieve an optimal composition. The plant can be designed for the specific materials contained in the wastewater instead of operating to deal with a range of concentrations of differing materials, as does the small municipal plant. Greater cost consciousness on the part of industrial management, too, may be a factor acting to stimulate efficiency.

(2) Combining substantial industrial waste discharges with municipal wastes tends to move unit construction costs substantially downward. Again, this is a reasonable and expected situation, where the industrial wastes are suitable for conventional waste treatment. The usual composition of munici-

FIGURE II - 6

COMPARATIVE CONSTRUCTION COSTS PER UNIT OF FLOW, SECONDARY WASTE TREATMENT PLANTS



pal wastes is relatively deficient in nutrients, the industrial waste is often deficient in operative bacteria. Highly concentrated wastes of some manufacturing processes, then, tend to bring the municipal plant closer to the efficiency possible when an optimum loading pattern is attained. When a significant portion of industrial wastes originate from plants operating on a single shift, the hydraulic pattern, too, may approach an optimum, since the normal daily loading pattern of a municipal plant is complementary with industry's normal day shift; or industrial discharges may be scheduled to coincide with treatment plant operating cycles. Finally, in many cases, the industrial waste is higher in temperature, which tends to accelerate the life processes of the bacteria that sustain decomposition.

(3) The unit cost of constructing industrial waste treatment systems appears to be declining. When adjustments are made for price level changes, systems built prior to 1960 cluster above the average cost curve while treatment systems built since 1965 tend to fall below the curve.

(4) The cost of waste treatment probably differs significantly among industries. This would not seem surprising, but fundamental waste treatment processes are similar for wastes from most sources, while hydraulic loading is a constant sizing factor. It would seem, however, that opportunities for segregation of the components of the waste stream, pretreatment requirements, and the rate of assimilation vary significantly among industries. There is at least a hint in the analyzed data that unit costs are relatively high for petroleum refineries and some segments of the chemical industry, while food processing and pulp and paper - readily adaptable to conventional waste treatment procedures - tend to require lesser investments per unit of wastewater. Industrial Waste Profiles support the conclusion.

(5) On the basis of the very limited data, it would appear that unit costs tend to exhibit a sharper drop with increase in size of plant than is characteristic of municipal waste treatment plants. The tendency has been indicated in a prior study of municipal waste treatment plant construction costs, where it was found that "...the cost [per unit wasteload] curves have a greater slope than the cost per capita curves. This slope differential evidently is caused by the

increasing percentage of industrial wastes with increasing population..."[8]

METHOD OF ASSESSMENT

From the point of view of the economist attempting a gross assessment of total industrial waste treatment costs, uncertainties regarding specific costs are largely irrelevant. Gross aggregation and consistent application of statistical method can cut through the complexities caused by the wide range of options available within the open system of the industrial plant to produce a generalized estimate of the cost of providing a fixed level of waste treatment efficiency. If it is assumed: (1) that all of the data are equally valid and reliable; (2) that normal cost and efficiency standards apply; and (3) that the equivalent of secondary waste treatment (i.e., no less than 85% removal of standard BOD and of settleable and suspended solids) provides an adequate definition of the efficiency goal, then a normative assessment of costs can be made. We may say that within the limits of current technology, 85% of the volume of settleable and suspended solids and of oxygen-demanding dissolved organics contained in the wastewater of manufacturing firms using 20 million gallons or more of water per year can be reduced by an expenditure of roughly x dollars.

That is the form which this study takes. If the data were better, the analysis more detailed, the estimate might be more precise in its formulation. It is doubtful, however, that it would be more reliable. Only a plant-by-plant analysis that fully considers alternatives available within the limits of law, technology, and custom in terms of both the physical environment and local economic developmental patterns would be wholly reliable. Lacking that assessment, the method should prove adequate to provide preliminary cost estimates required for planning and budgeting purposes.

This cost assessment is based upon a specific, quantitative goal: complete application to industrial wastewaters of waste reduction efficiencies equivalent to that of secondary treatment of domestic wastes. The introduction of a specific goal makes this analysis possible. It should be noted, however, that in any particular situation secondary treatment may represent a distinct departure from actual needs.[9] Recognizing that conditions may sometimes require higher or lower efficiencies, the analytical goal of secondary-level removal was chosen on the basis of the technical decision that it most closely approximated the condition required to satisfy water quality standards in the aggregate.

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[8] *Modern Sewage Treatment Plants - How Much Do They Cost?, p. 25. The analysis does not pursue the indicated conclusion. It is possible, too, that the time of construction has an effect on the data, with many of the larger secondary plants being built relatively recently. Ultimate resolution of questions of this sort will have to await a period when waste treatment activities are more responsive to cost, and a larger body of cost data is available.*

Given the specific goal of complete secondary waste treatment, it was possible to evaluate the cost of attaining that goal. The method utilized was consistent, rigid, but, within the limits of data reliability, it is felt adequate to provide an approximate assessment of the magnitude of the cost associated with the analytical goal.

Cost data were derived from the considerable body of material that has been accumulated through the machinery of the Federal Construction Grants program analyzed in Modern Sewage Treatment Plants - How Much Do They Cost? and updated by application of the Engineering News Record Index of Construction Costs. The data refer only to municipal plants, but it was felt that a formula that related varying elements of the costing equation could be applied to industrial plants in view of the demonstrated effectiveness of conventional waste treatment techniques in reducing organic wastes from all sources, and the observed general correspondence of municipal and industrial construction costs demonstrated in Figure II-6.

Industrial water use data were obtained from the Census of Manufactures. Information contained in the Census covered less than 11,000 of the more than 300,000 manufacturing establishments in the nation. But the establishments included all of those with an intake of 20 million gallons or more of water a year, and account for about 97% of all water withdrawn for manufacturing use. The group, then, may be assumed to include every significant industrial source of water pollution, as well as the entire body of manufacturers whose waste treatment investment requirement can be calculated.

Industrial waste loadings and concentrations were derived from a previous study conducted by FWPCA. This study, summarized in Table II-2, attempted to assess the total pollutional loading produced in the base year 1964 by manufacturing plants. While an attempt was made by the investigators to gage the magnitude of a broad range of pollutants, this cost analysis limited itself to consideration of the total annual volume of standard BOD, a key factor in sizing secondary waste treatment plants.

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[9] *A modification of the goal was instituted for this reason. Secondary waste treatment involves the biological decomposition of organic wastes. The analysis of conventional waste strengths associated with manufacturing processes indicated that the average concentrations of oxygen-demanding organic wastes in the discharges of the primary metals, inorganic chemicals, and machinery industries is less than that of some natural waters. For this reason, waste treatment requirements for those industrial sectors were scaled on the basis of primary treatment.*

Given the number of industrial plants, the average daily discharge and BOD concentration of wastewaters, the average cost for constructing a treatment plant of a given size, and the approximate level of waste treatment in each industrial sector in 1964, it was possible to calculate:

(1) a total number of waste treatment plants required in each industry,

(2) a cost for the average large plant (discharge of 100 million gallons per year or more) and the average small plant (discharge of 20 to 99 million gallons per year) in each industry,

(3) the number of waste treatment plants available in each industry in 1964 and, by straight line projection, in 1968, and

(4) the deficiency in number of treatment plants, and an amount equal to the percentage of plant value represented by the percentage of required plants actually available.

The figures obtained rested entirely on application of average construction costs to numbers of plants of average size classes. The data were subsequently modified to include information obtained in "profiles" of waste treatment requirements of 10 major water-using industries. For the most part, the outlines of investment requirements developed in the profiles adhered within practical limits to the requirements developed through the analysis of the census materials. One major exception should be noted. In almost every case the profile suggested a higher prevalence of waste treatment than did projection of census-developed data. It would appear that either American industry built waste treatment plants during the period 1964 to 1967 at a rate much accelerated over that of the previous five years, that the form in which the census data were collected and reported understated the prevalence of waste treatment in 1964, or that some consistent bias was built into the profiles.

Accordingly, the data presented in the following pages are to be considered a generalized model of costs associated with achieving an 85% reduction of standard BOD and of settleable and suspended solids generated by major industrial establishments. While the figures are based on the assumption of use of conventional methods and normal cost relationships, it may be anticipated that techniques presently available and yet to be developed will be utilized to reduce costs below the indicated values. It must be recognized, too, that though studies of a number of industrial segments were utilized in an attempt to build into the model's structure an appreciation of waste treatment problems and methods peculiar to specific kinds of industries, there must inevitably be great variations in detail which can change the indicated requirement for any industrial sector.

In spite of these reservations, it is believed that the reported requirements provide a useful indication of both the gross magnitude of industry's waste-associated costs, and the inter-industry distribution of those costs.

TOTAL REQUIRED INVESTMENT FOR INDUSTRIAL WASTE TREATMENT

Table II-12 summarizes, by industrial classification, the total investment required to achieve an 85% reduction in gross industrial wastes under current (FY 1968) conditions. In view of the volume of such wastes, the amount is surprisingly small - about $4 billion. Even more surprising is the high indicated prevalence of industrial waste treatment. The analysis indicates that the unmet requirement for industrial waste treatment plants amounts to little more than $1 billion.

It should be noted that the values depend in large measure on data provided in Volume III, Industrial Waste Profiles, the waste treatment requirements of 10 major water-using industries. Calculations based entirely on census data and municipal construction costs developed a total indicated requirement for industrial waste treatment works of more than $5 billion - about 30% higher. More significant, they revealed a total unmet requirement of $2,644 million, more than twice the level reported in Table II-12. Moreover, there were some meaningful shifts among the requirements for specific industries when the data of the profiles were applied. Before adjustment for such information, a much higher total investment requirement and a proportionately lower additional requirement was calculated for the chemicals industries; a higher investment requirement and a proportionately far higher unmet requirement was calculated for the paper and allied products industries; and a slightly lower total requirement combined with a much higher unmet requirement was calculated for the primary metals industries.

The set of figures that reflect the information provided in Volume III, Industrial Waste Profiles, was selected for more detailed presentation and analysis on the basis that it included all of the available information. Still, policy makers should keep in mind the fact that costs presented in this report are lower than others developed for the same report (as well as much lower than some undocumented assessments made on other occasions) and should not, therefore, be regarded as completely reliable. To indicate the possible range of costs involved, succeeding tabular materials will provide a summation of relationships under both sets of values, though the discussion will be restricted, in large part, to the values obtained through application of the profile information.

The arguments for making full use in this report of cost relationships developed by the wastewater profiles rather than the higher, census-derived, assessment are these:

(1) They reflect experience and expert observation in specific industry situations; data derived from census analysis and municipal cost relationships do not. Thus the steep indus-

TABLE II-12

ESTIMATED VALUE OF INVESTMENT, INDUSTRIAL WASTE TREATMENT REQUIREMENTS, 1968

(Based on Industrial Waste Profiles)

Industry	Millions of 1968 Dollars			
	Total Plant Required	Currently Provided By Municipalities	Currently Provided By Industry	Additional Investment Required
Food and Kindred Products	743.1	340.7	182.4	220.0
Meat Products	170.8	98.7	36.9	35.2
Dairy Products	104.0	73.1	7.8	23.1
Canned and Frozen Foods	137.0	80.0	23.0	34.0
Sugar Refining	175.2	2.3	105.5	67.4
All Other	156.1	86.6	9.2	60.3
Textile Mill Products	165.2	85.4	53.3	26.5
Paper and Allied Products	321.8	21.1	225.0	75.7
Chemical and Allied Products	379.7	12.0	87.9	279.8
Petroleum and Coal	379.4	27.4	275.0	77.0
Rubber and Plastics	41.1	5.1	5.1	30.9
Primary Metals	1,473.8	55.1	1,269.2	149.5
Blast Furnaces and Steel Mills	963.8	-	865.6	98.2
All Other	510.0	55.1	403.6	51.3
Machinery	39.0	11.2	2.9	24.9
Electrical Machinery	35.8	22.8	4.5	8.5
Transportation Equipment	216.0	115.1	59.2	41.7
All Other Manufacturing	203.7	35.5	50.8	117.4
All Manufactures	3,998.6	731.4	2,215.3	1,051.9

trial waste treatment unit cost curve presented in Figure II-6 seems to be borne out in contrasting the preliminary $5 billion cost assessment with the amended $4 billion requirement.

(2) Census data are partial and unweighted, and generalized assumptions used to modify them may well be in error - in greater or lesser degree - in the case of specific industries.

(3) The profiles account for cost-reducing steps customarily taken in the plant to reduce the volume and strength of wastes prior to treatment. Such procedures could only be roughly approximated in the model that utilized census data.

(4) In the judgment of the authors of the profiles, most industries would seem to have been constructing waste treatment facilities at a more rapid rate over the last four years than during the five previous years. Thus the simple projection of 1959 to 1964 plant construction rates used in the analysis of the census perhaps overstates the unmet requirement.

(5) The profiles provide an insight into the peculiar waste treatment requirements of specific industries, thus are more precise than a general goal such as "the equivalent of secondary treatment of domestic wastes." When specifics are brought into the equation, the experience of industries that have dealt with them on the basis of meaningful alternatives is reflected - and with it the weighting of cost experience provided by use of optimal methods.

(6) A weakness of the profiles, as opposed to the census, as a source of data is that they tend to be based on limited geographical experience. Thus the waste treatment situation of a regional segment of an industry may, without proper justification, be used to generalize the total industry's practices. It is probable, for example, that the problem presented by the obsolescent sulfite pulping plants of Wisconsin and the Pacific Northwest could at least double indicated requirements for the paper and allied products group.

Table II-13 summarizes the differences in evaluation that occurred with the two sets of calculations. The significant variation between the value of plant in place as calculated by the separate methods gives further point to the need expressed by the FWPCA, through a number of program proposals over

TABLE II-13

COMPARISON OF ESTIMATED 1968 WASTE TREATMENT REQUIREMENTS UNDER TWO METHODS OF CALCULATION

Industry	Millions of 1968 Dollars	
	Basis For Estimate	
	Wastewater Profiles and Estimates	Census-Municipal Projections
Food and Kindred Products	743.1	669.6
Meat Products	170.8	128.6
Dairy Products	104.0	69.3
Canned and Frozen Foods	137.0	155.8
Sugar Refining	175.2	175.2
All Other	156.1	140.7
Textile Mill Products	165.2	170.9
Paper and Allied Products	321.8	917.6
Chemical and Allied Products	379.7	1,003.8
Petroleum and Coal	379.4	272.3
Rubber and Plastics	41.1	58.9
Primary Metals	1,473.8	1,383.7
Blast Furnaces and Steel Mills	963.8	890.7
All Other	510.0	493.0
Machinery	39.0	55.9
Electrical Machinery	35.8	51.3
Transportation Equipment	216.0	156.4
All Other Manufacturing	203.7	291.8
All Manufactures	3,998.6	5,032.2
Plant Currently Provided By Industry	2,215.3	1,752.3
Plant Currently Provided By Municipalities	731.4	635.9
Unmet Requirement	1,051.9	2,644.0

the years, for an inventory of industrial waste sources and waste treatment. For while deficiencies of the census as a source of data may explain a part of the difference, and the high dollar efficiency of industrial waste treatment investments relative to municipal investments may also provide a partial explanation, the wide spread between the two estimates is perplexing. It is possible that the variation in indicated investment reflects an industry-wide deficiency in normal waste treatment capacity. If the difference between the separate assessments of unmet requirements were proportional to incremental industrial wasteloads reaching watercources as a result of under capacity in existing waste treatment, there would be clear cause for concern.

There is a hint in the Industrial Waste Profiles that some such mechanism is actually at work. For example, the estimated efficiency with which the steel industry operates its waste-reducing plant is, according to the profile, only 50%. Similarly, the profile of the plastics and resins industry suggests that waste reduction efficiencies based on reduction of standard BOD are deceptive. Many waste constituents are not removed by conventional treatment processes; and removal of five-day BOD provides an ineffective yardstick for evaluating treatment effectiveness where a large proportion of the wastes produced are of a persistent nature. Oxygen demand is asserted in such cases well after the five-day period when 67% of the stabilization of sanitary wastes takes place.

It is clear that, whichever set of unmet treatment requirements is utilized, industry does not face a major investment to bring its waste treatment capabilities up to the standard of removal set as a goal. But in planning to meet industrial pollution control costs, the unmet requirement should not be considered to be their only, or even their major, source. Substantial sums will be needed to keep pace with removal standards as industrial output increases; and large amounts will have to be expended each year to operate, maintain, and replace elements of the waste removal system.

Table II-14 presents an assessment of investment requirements which must be met if industrial wastes are to be controlled within the next five years to the average level of efficiency used as a standard for this report. The underlying assumptions are that: (1) existing unmet waste treatment requirements will be provided equally over each of the next five years; and (2) no additional unmet requirements will arise (i.e., all new plant construction or other additions to capacity will include adequate waste treatment facilities whose cost is assessed in the schedule).

The table indicates that industry will have to invest over a third of a billion dollars a year to keep pace with the growth of its waste treatment responsibilities and to eliminate existing deficiencies. (If the higher indicated requirements and the greater preponderance of deficiency indicated by the analysis of the census is used for a base, the total industrial investment requirement over the same five-year period would amount to over $3.6 billion.)

TABLE II-14

ANNUAL INVESTMENT REQUIRED TO REDUCE THE EXISTING INDUSTRIAL WASTE TREATMENT DEFICIENCY IN FIVE YEARS

(Wastewater Profiles and Estimates)

Industry	Millions of 1968 Dollars					
	Annual Investment To Reduce Existing Requirement	Total Investment to Reduce Waste Treatment Requirements and Meet Growth Needs				
		1969	1970	1971	1972	1973
Food and Kindred Products	43.9	63.2	65.4	69.9	70.0	69.9
Meat Products	7.0	10.1	11.2	11.2	11.7	11.6
Dairy Products	4.6	5.1	5.7	5.5	5.5	5.5
Canned and Frozen Foods	6.7	11.4	12.4	12.6	12.9	13.0
Sugar Refining	13.5	19.3	18.4	22.6	21.4	21.5
All Other	12.1	17.3	17.7	18.0	18.5	18.3
Textile Mill Products	5.3	9.8	10.9	11.1	11.0	11.6
Paper and Allied Products	15.1	19.1	25.5	26.0	26.4	27.0
Chemical and Allied Products	56.0	75.7	76.9	77.7	79.4	77.9
Petroleum and Coal	15.4	15.4	18.1	30.5	31.7	32.1
Rubber and Plastics, n.e.c.	6.2	7.0	7.9	7.1	7.2	7.1
Primary Metals	29.9	83.6	91.3	93.3	96.2	97.8
Blast Furnaces and Steel Mills	19.6	52.4	59.1	60.1	63.0	63.0
All Other	10.3	31.2	32.2	33.2	34.2	34.8
Machinery	5.0	6.9	6.9	7.1	7.1	7.3
Electrical Machinery	1.7	3.6	3.8	3.8	4.0	4.1
Transportation Equipment	8.3	11.7	11.9	12.2	12.1	12.3
All Other Manufacturing	23.5	32.3	32.6	33.0	33.5	33.8
All Manufactures:						
By Wastewater Profiles and Estimates	210.3	328.3	351.2	371.7	378.6	380.9
(By Census-Municipal Projections)	(528.5)	(676.9)	(705.8)	(731.5)	(740.2)	(743.1)

The required increase in waste treatment that will result from growth of industrial output over the five-year period will constitute a significant sum. Starting at over $100 million per year in 1969, the annual total adds about $20 million in each succeeding year, on a schedule based on projections of output provided by the Business and Defense Services Administration of the U. S. Department of Commerce.[10]

By FY 1973, it is assumed that American industry will be installing water pollution control equipment for new and expanded plants at a roughly $200 million annual rate. In addition, depreciation charges on $4.4 billion of waste treatment plants in place (including municipal plants serving industry) will be accruing at an annual rate of $238 million, assuming a normal 20-year period of depreciation. Thus total annual capital requirements will exceed half a billion dollars a year, even after indicated industrial waste treatment requirements have been met.

In sum, the amount should not have a depressing effect on any industry. If one considers that new plant and equipment expenditures in manufacturing amount to almost $30 billion annually at existing rates of investment, the $400 to $500 million annual waste treatment investment foreseen after the period of catching up has ended will amount to roughly one and a half percent of industry's annual plant and equipment investment.

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[10] *The assumption in making the projection was that waste treatment requirements would increase proportionately with values added, adjusted for price level changes. In several industries - transportation equipment, petroleum refining, dairy products - waste treatment requirements were projected at a lesser rate of increase than values added to reflect the judgment of industry specialists (as presented in Volume III, Industrial Waste Profiles), that growth in capacity will not be commensurate with growth in output.*

MARGINAL EFFICIENCY AND HIDDEN COSTS

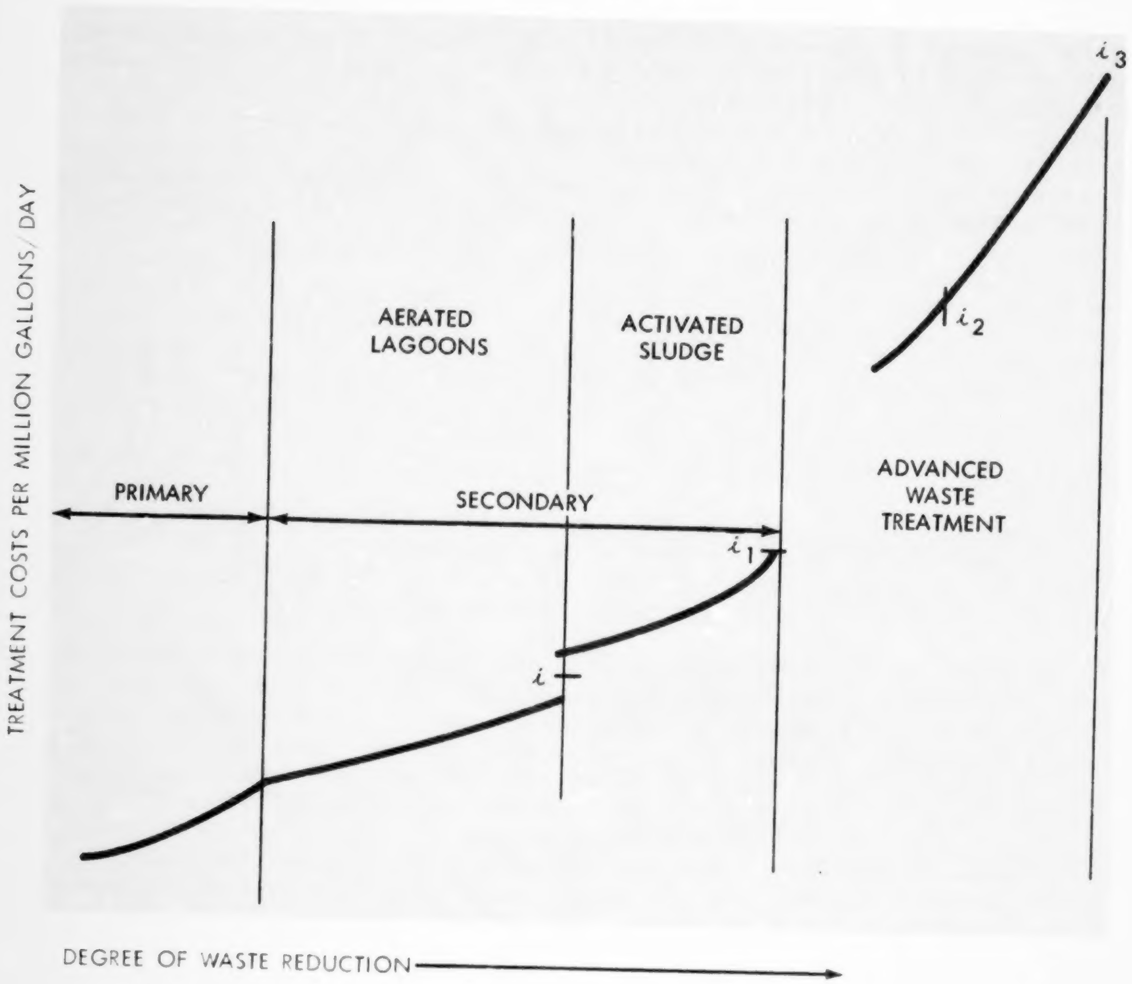
Ultimately the cost of pollution control must be measured in each drainage basin, in terms that include the peculiar hydrologic, climatic, and economic configurations of the river system. A national assessment, to be dependable, must be built painstakingly from the bottom up, to reflect water quality standards and factors affecting water quality in each drainage area. The generalized waste treatment goal utilized in this report must be recognized to provide only a first effort to set the terms for detailed regional and industrial studies that take into account specialized circumstances that affect costs.

One of the most significant of these is the extreme increase in costs that is incurred when advanced waste treatment becomes a necessity. Figure II-7, developed by W. W. Eckenfelder of the Department of Engineering at the University of Texas, generalizes the cost relationships associated with progressive levels of waste removal efficiency. The curve's shape and known relationships between the cost of primary treatment, aerated lagooning, and activated sludge indicate that the relationships are arithmetic rather than logarithmic.

It is obvious from the shape of the conceptualized treatment cost curve that marginal reductions in wastes involve sharp increases in unit costs. Between primary and secondary waste treatment, costs roughly double. From secondary to tertiary treatment, cost increase is even more pronounced.

These relationships are critical in assessing the validity of the $4 billion to $5 billion treatment cost estimates. Those costs are associated with a selected point - 85% removal of the suspended solids and biochemical oxygen demand of sewage. It is generally recognized, however, that the relationships between secondary waste treatment (85% removal) and attainment of water quality standards is not a fixed one. In some instances primary waste treatment may be adequate to maintain stream quality. On the other hand, there are a number of instances - and that number must grow, with incremental increases in waste volume - where secondary waste treatment will be inadequate to achieve an established standard. This is particularly true of industrial wastes. Secondary waste treatment reduces oxygen demand and settleable and suspended solids; but in many cases, industrial wastes are characterized by persistent rather than standard biochemical oxygen demand, by toxics, by exotic compounds, by dissolved minerals. Reduction of such waste constituents cannot be achieved with secondary waste treatment, and it is necessary to apply some form of advanced (tertiary) or specific treatment process. In view of the sharply increased costs involved in attaining advanced treatment, it may be expected that industrial waste treatment costs may in fact exceed considerably those presented in this report. Much of what is considered advanced waste treatment in the case of sanitary sewage or municipal wastes may be the required form for many industrial establishments.

FIGURE II-7
GENERALIZED RELATIONSHIP BETWEEN WASTE TREATMENT COSTS AND INTENSITY OF TREATMENT



After W.W.Eckenfelder: Effluent Quality and Treatment Economics for Industrial Wastewaters, October 1967

Lacking a technical assessment of the relative significance of this circumstance, the analyst may still obtain some view of its potential impact on cost. If it is assumed that the cost relationships indicated by W. W. Eckenfelder's curve are generally valid and that the curve presents them accurately, application of the measured costs of secondary industrial waste treatment at points along the curve provides some index of the growth in the magnitude of the total investment requirement associated with more complete removal of industrial wastes.

The operative assumption in preparing this report is the presumption of a level of waste removal that correlates theoretically with point i along the curve (Figure II-7). The point is considered to represent the level of cost that corresponds with 85% BOD removal. Point i_1 may be assumed to represent about 90% removal of BOD. Point i_2 may be said to correspond with 95% BOD removal, some indeterminate level of reduction of persistent organic materials and/or dissolved inorganics; point i_3 indicates a level of cost associated with removal of more than 98% of BOD and/or an increased level of removal of persistent organics and dissolved inorganics.

If all industrial waste treatment investments are evaluated in terms of 85% removal - at the primary treatment level and each of the sequence of points indicated along the curve - relative costs may be derived at successive incremental efficiences, as indicated in the following table:

TABLE II-15

CAPITAL COSTS ASSOCIATED WITH VARYING LEVELS OF INDUSTRIAL WASTE TREATMENT EFFICIENCY FOR 1968 DISCHARGES

Type of Treatment	Assumed BOD_5 Removal	Indicated Total Investment	
		Wastewater Profiles and Estimates	Census-Municipal Projections
Primary	35%	$ 2.3 billion	$ 2.9 billion
Secondary	85%	$ 4.0 billion	$ 5.0 billion
Secondary	90%	$ 6.0 billion	$ 7.5 billion
Tertiary	95%	$10.6 billion	$13.3 billion
Tertiary	98%	$13.4 billion	$16.8 billion

These are, of course, approximate kinds of relationships. It is clear, however, that as we move into the actual implementation of water quality standards - where varying levels of treatment will be demanded by conditions - diminishing returns may act to increase costs enormously.

(Not only industrial waste treatment costs will be affected. The less exotic wastes of municipalities, by reason of their great volume at points of population concentration, will pose an increasing need to face the costs of installing and operating advanced waste treatment procedures. Relying on the relationships of the Eckenfelder curve, we may conclude that for every 10% of the nation's urban population that is required to increase its waste treatment efficiency to 95% BOD removal, an additional $1.3 billion investment will be required. With more than two-thirds of the nation's population concentrated in 222 standard metropolitan statistical areas, it is obvious that an increasing number of municipal areas are expanding to a point where the volume of their waste discharges will make just such an investment decision necessary.)

OTHER SOURCES OF COST

There are other, undefined, kinds of costs associated with treatment of industrial wastes which may have the effect of pushing total costs well above those derived from the methods and assumptions embodied in this analysis.

Technical experts are in general agreement that reduction in standard BOD is an inadequate guide for measuring the efficiency of waste treatment where wastes are other than conventional sanitary sewage. There is a hidden cost component of indeterminable magnitude in that portion of the industrial waste treatment plant now in place which is operating in an ineffective manner.

Loss of practical efficiency of sunk capital is sometimes involved in circumstances where a conventional waste treatment procedure is applied to industrial wastes which may have quite separate characteristics from those of sanitary sewage. In the case of potato processing wastes, for example, there is evidence that conventional secondary waste treatment simply serves to incubate slow-stabilizing wastes, so that they are discharged to watercources near their maximum oxygen-demanding potential.

A general problem is the fact that stabilization of organic materials in the treatment process results in release of nitrogen and phosphorous in a mineral form, which is swiftly utilized by aquatic biota. Given a primary level of waste treatment, natural stabilization takes place over an extended area of stream, where biologic productivity is regulated by rate of nutrient release. With the introduction of secondary waste treatment, nutrients are immediately available, production of algae and other biota is accelerated, and is sometimes attended by disagreeable slime growths. The situation is increasingly prevalent in many western and midwestern drainage systems, where it may force early adoption of some form of advanced waste treatment.

Another kind of cost increment is inherent in the assumption that the presence of a treatment plant of a given description indicates a normal removal of waste constituents. Experience has taught that this is simply not true. Treatment plants may be undersized, under-maintained, inadequately operated. Factories are operated for other purposes than waste reduction - in pollution-controlling terms - so their waste treatment plant operators tend to be non-professionals and, except in circumstances involving enforcement proceedings, waste treatment often does not receive a high priority in allocation of management effort. In many cases, treatment plants may be said to be built simply to escape the nuisance presented by the regulatory agency. Under-designed, under-engineered, and under-operated industrial waste treatment plants may be very common. If one considers the South Platte River Basin, for example, he finds that the census of water use indicates that all but one of the sugar refineries in the area had some sort of ground disposal system in operation in 1964, thus would be assumed to have adequate waste treatment. Investigation of the plants in the conduct of an enforcement conference revealed, however, that normal BOD removal efficiency was in the neighborhood of 10 to 25% rather than the assigned average efficiency of 85%. Similarly, Volume III, Industrial Waste Profiles, prepared for the standard industrial classification "blast furnaces and steel mills" offered the judgment that, industry-wide, waste treatment facilities are operated only at 50% of standard or expectable efficiency. To the extent that attainment of normal operating efficiency may require additional expenditure, capital requirements are understated; and the possible effects of this mechanism remain to be evaluated.

ANNUAL COSTS OF INDUSTRIAL WASTE TREATMENT

The estimated $1 billion to $2.6 billion that industry will have to expend over the next five years to end the deficiency in its waste treatment capabilities will be most burdensome not as an investment requirement but through its effects on industrial cost structures. Once built, the waste treatment system must be operated and maintained, so that as the capital investments are made, operating costs will rise.

Analytical work on operating and maintenance costs associated with industrial waste treatment has been extremely scarce. When, as occasionally happens, such costs are quoted in the technical literature, they tend to be expressed in terms of costs - including interest, depreciation, and taxes - per pound of BOD removed. An assemblage of data prepared by W. W. Eckenfelder (Effluent Quality and Treatment Economics for Industrial Wastewaters) cited operating and maintenance costs for more than 50 industrial waste treatment systems; but the variation in expression of unit costs, treatment efficiency, and value of plant made it impossible to derive meaningful relationships between investment and operating costs. Volume III of this report, the Industrial Waste Profiles, probably contain the only existing publicly available analyses of operating costs for any significant segment of industrial wastewater treatment.

Operating costs have been abstracted from the profiles, and expressed in terms of percentage of current replacement value of investment in Table II-16. The cost relationships indicated in the table were used to derive estimated annual operating and maintenance costs for all manufacturing industries for the period 1968-1973, on the assumption that operating costs for a total industrial sector would be similar to those for the segment of the industry profiled, and that other industrial groups would face operating costs similar to average costs for all of the profiled industries.

Applying the operating cost ratios to the assumed schedule of investment, Table II-17 presents the calculated annual cost to industry of operating the waste treatment system assumed to be necessary to maintain water quality standards. Operating and maintenance costs, as presented in the table, include assessment of sewer charges for municipally treated wastes at the same rate as operating costs incurred by factory-operated treatment plants. As the backlog of needed plants is worked off and industrial output increases over the period, the annual cost of operating treatment plants is seen to rise almost 60%, and to amount to almost three quarters of a billion dollars by 1973 - or almost a billion dollars if municipal capital cost relationships are applied.

Unlike construction costs, operating and maintenance costs tend to be higher on a unit basis for industrial waste treatment than for municipal. The

TABLE II-16

ANNUAL OPERATING AND MAINTENANCE COSTS AS A PERCENTAGE OF VALUE OF TREATMENT PLANTS

Industry	Operating and Maintenance Costs as Percent of Current Replacement Value
Fibers, Plastics and Resins	21.2
Textile Mill Products	28.1
Canned and Frozen Foods	17.4
Meat Packing	11.3
Dairy Products	20.0
Motor Vehicles	16.9
Blast Furnaces and Steel Mills	10.4
Pulp and Paper	13.6
Petroleum Refining	20.0
Mean for Nine Industries	17.7

TABLE II-17

ANNUAL OPERATING AND MAINTENANCE COSTS
1968-1973

Industry	Annual Operating and Maintenance Costs (Millions of 1968 Dollars)					
	1968	1969	1970	1971	1972	1973
Food and Kindred Products	85.4	95.9	107.0	118.7	130.4	142.1
Meat Products	15.3	16.4	17.7	19.0	20.3	21.6
Dairy Products	16.1	17.1	18.3	19.4	20.5	21.6
Canned and Frozen Foods	17.9	19.9	22.0	24.2	26.5	28.7
Sugar Refining	19.1	22.5	25.8	29.8	33.5	37.3
All Other	17.0	20.0	23.2	26.3	29.6	32.9
Textile Mill Products	39.0	41.7	44.8	47.9	51.0	54.3
Paper and Allied Products	33.3	35.9	39.3	42.8	46.4	50.0
Chemical and Allied Products	21.1	37.2	53.5	70.0	86.8	103.3
Petroleum and Coal	60.5	63.6	67.2	73.3	79.6	86.1
Rubber and Plastics, n.e.c.	1.8	3.0	4.4	5.7	7.0	8.2
Primary Metals	137.8	146.5	155.9	165.7	175.7	185.9
Blast Furnaces and Steel Mills	90.1	95.5	101.6	107.9	114.4	121.0
All Other	47.7	51.0	54.3	57.8	61.3	64.9
Machinery	2.5	3.7	4.9	6.2	7.5	8.7
Electrical Machinery	4.8	5.5	6.1	6.8	7.5	8.2
Transportation Equipment	29.4	31.4	33.4	35.5	37.5	39.6
All Other Manufacturing	15.3	21.0	26.8	32.6	38.5	44.5
All Manufactures:						
By Wastewater Profiles and Estimates	430.9	485.4	543.3	605.2	667.9	730.9
By Census-Municipal Projections	(348.7)	(453.6)	(565.6)	(679.9)	(802.1)	(921.7)

causes are functions of the same phenomena that result in high cost effectiveness of the industrial waste treatment investment. More concentrated industrial wastes induce greater materials handling costs per unit of wastewater or per cubic foot of treatment capacity than is true of the municipal plant. Similarly, the evening of the industrial flow pattern that allows a smaller industrial treatment plant to handle the same volume of wastewater as a larger municipal plant, with its fluctuating daily flow pattern, results in a treatment system that is operating closer to capacity, thus with higher costs per unit of capacity. Finally, it should be noted that the industrial operating cost often includes a larger measure of pretreatment and post-treatment operations. The typical municipal treatment system is, except for disinfection, a continuous process. Industrial wastes often require neutralization, screening, segregation, dilution, and other ancillary processes in addition to treatment or to sewering.

Operating and maintaining the nation's industrial waste treatment plant will provide the major element in the sustained, rising total cost of industrial water pollution control, once the existing deficiency in waste treatment capabilities has been ended. Even if an equilibrium position is attained by 1973, with no waste treatment requirements other than those imposed by replacement and expansion, the total annual increment to manufacturers' cash requirements represented by water pollution control will exceed a billion dollars a year. Table II-18 summarizes, for all manufacturing, the rising requirements posed by waste treatment through the period 1969-1973. After 1973, industry will face a situation in which it must be prepared to expend an annual investment rising from a base of about $200 million a year to provide for output growth,* pay operating and maintenance costs rising from over $730 million a year, and face replacement costs - as measured by depreciation - increasing steadily from the 1973 base rate of about $200 million per year.

Clearly, waste treatment will occupy an increasingly significant place in determining the total costs and the financial requirements of industrial operations.

**Note:* *The values are obtained by subtracting from the indicated 1973 capital requirement, that portion needed to eliminate existing deficiencies (Table II-14).*

TABLE II-18

ANNUAL CASH OUTLAYS ASSOCIATED WITH THE PROJECTED INDUSTRIAL WASTE TREATMENT SYSTEM, 1969-1973

Source of Outlay	Millions of 1968 Dollars					
	1969	1970	1971	1972	1973	5-Year Total
By Wastewater Profiles & Estimates:						
Depreciation/Replacement @ 5%	127.2	144.7	163.3	182.3	201.3	818.8
Operation & Maintenance	485.4	543.3	605.2	667.9	730.9	3,032.7
New Plant Required	328.3	351.2	371.7	378.6	380.9	1,810.7
Total Outlays	940.9	1,039.2	1,140.2	1,228.8	1,313.1	5,662.2
(Replacement Value, Plant in Place)1/	(2,543.6)	(2,894.8)	(3,266.5)	(3,645.1)	(4,026.0)	
By Census-Municipal Projection:						
Depreciation/Replacement @ 5%	121.5	156.8	193.3	230.3	267.5	969.4
Operation & Maintenance	453.6	565.6	679.9	802.1	921.7	3,422.9
New Plant Required	676.9	705.8	731.5	740.2	743.1	3,597.5
Total Outlays	1,252.0	1,428.2	1,604.7	1,772.6	1,932.3	7,989.8
(Replacement Value, Plant in Place)1/	(2,429.2)	(3,135.0)	(3,866.5)	(4,606.7)	(5,349.8)	

1/ *Excludes value of treatment through municipal systems in 1968. Projections of the incidence of municipal treatment of industrial wastes presented in the chapter on Municipal Waste Treatment Requirements indicate that the current replacement value of plant in place at each of the projection years will include a municipally provided component amounting to:*

Year	By Wastewater Profiles and Estimates	By Census-Municipal Projections
1968	$731.4 million	($635.9 million)
1969	$775.3 million	($674.1 million)
1970	$821.8 million	($714.5 million)
1971	$871.1 million	($757.4 million)
1972	$923.4 million	($802.8 million)
1973	$978.8 million	($851.0 million)

REGIONAL INCIDENCE OF INDUSTRIAL WASTE TREATMENT COSTS

Distribution of industrial waste treatment requirements among the regions of the nation is affected by a variety of factors. The relative degree of industrialization, the type of manufacturing industries that characterize the region, and the relative age of plants in various industries are the principal elements that enter into the determination of industrial waste treatment requirements. In addition to these, scarcity or abundance of water supplies and the vigor with which pollution control laws are enforced tend to affect strongly the level of plant in place relative to required plant.

Regional allocations, as presented in Table II-19, of the estimated current industrial waste treatment investment requirement reflect only two of the factors that bear upon actual cost distributions. The table adequately mirrors degree of industrialization and manufacturing specialization among regions. It fails to account for relative average age and size of plant, or effects of regional water pollution control programs; these elements cannot be gaged accurately in the absence of an inventory of industrial waste sources.

The method of distribution involved allocation of costs by industry, according to the identifiable portion of each industrial sector's total wastewater discharge that occurs within each of the regions. The unidentifiable portion of the cost was allocated porportionately to each region's share of the total unidentifiable industrial water discharge.

Since the major factors influencing industrial waste treatment requirements (number and kind of manufacturing users of water) are the elements underlying the tabulation, it should be of some value to state and regional planners who must consider the relative significance of waste treatment requirements in the total complex of regional development circumstances.

Waste treatment requirements are concentrated in the industrial northeast. The North Atlantic, Great Lakes, and Ohio drainage regions contain more than 60% of the nation's industrial waste treatment requirement, more than half of the indicated unmet requirement. (In view of the tendency for old, small plants to have a disporportionate share of the total treatment needs of any industry, there is reason to believe that this industrially mature portion of the nation actually contains an even greater proportion of the waste treatment requirement than the allocation indicates.) In distinction, the vast areas of the southwest - i.e., the Colorado, Great Basin, and California drainage areas - contain only 4% of the indicated treatment requirement. Not only are these areas relatively unindustrialized, they tend to contain industries whose waste-producing, water-using characteristics are minor; the

TABLE II-19

REGIONAL DISTRIBUTION OF WASTE TREATMENT REQUIREMENTS, 1968, BY WASTEWATER PROFILES AND ESTIMATES

Regions	Millions of 1968 Dollars		
	Total Plant Required	Value of Plant in Place	Additional Investment Required
North Atlantic	814.0	575.5	238.5
Southeast	276.1	208.0	68.1
Great Lakes	973.4	784.2	189.2
Ohio	658.5	526.7	131.8
Tennessee	80.4	47.8	32.6
Upper Mississippi	205.1	149.9	55.2
Lower Mississippi	230.1	144.8	85.3
Missouri	88.2	64.2	24.0
Arkansas-White-Red	49.2	33.0	16.2
Western Gulf	286.8	168.9	117.9
Colorado/Great	25.9	17.0	8.9
Pacific Northwest 1/	167.6	121.1	46.5
California 2/	143.3	105.6	37.7
Total	3,998.6	2,946.7	1,051.9

1/ *Includes Alaska*

2/ *Includes Hawaii*

regions' 4% of the industrial waste treatment requirement is generated by plants producing 10% of national values added by manufacturers.

It should be recognized that the allocation of requirements by proportional industrial specialization probably provides a good guide to the dimensions of the total treatment requirement for any region, but a far less satisfactory indication of the relative deficiency in industrial waste treatment. Experience and judgment indicate that stringency and enforcement of pollution control regulations impose a significant influence on the prevalence of industrial waste treatment. Even more significant, perhaps, is the extent of the influences of water shortage and average age of industrial plant. Although the data do not permit quantitative expression of the effects of these influences, there are approximate numerical guides to its effect.

Table II-20 lists by region comparative percentage of total and treated industrial wastewater discharge found in the Census of Manufactures for 1964. Obviously, it is impossible to draw specific conclusions from the listings which reveal nothing about the kind or degree of treatment, relationships between wastewater discharge that requires treatment and other discharges, pollutional loading before and after treatment. Still, all things being equal, there is good reason to infer a distinct difference in regional practice. It may be anticipated that natural and recent historical circumstances will affect the actual resolution of regional cost allocations in ways that the information presently available does not allow us to measure.

TABLE II-20

RELATIVE REGIONAL PREVALENCE OF INDUSTRIAL WASTE TREATMENT, 1964

Region	Billion Gallons, 1964				Treated as % of Total
	Total Discharge	Treated Discharge			
		Treated Discharge 1/	Sewered Discharge	Ground Discharge	
North Atlantic	2,397	1,037	175	29	51.7
Southeast	893	315	48	12	41.9
Great Lakes	3,003	955	307	17	54.0
Ohio	2,370	400	167	15	24.6
Tennessee	387	109	10	10	33.3
Upper Mississippi	494	155	104	6	53.6
Lower Mississippi	572	133	20	3	27.3
Missouri	128	47	36	2	66.4
Arkansas-White-Red	174	82	14	2	56.3
Western Gulf	1,700	377	14	2	23.1
Colorado/Great	45	21	6	3	66.7
California/Hawaii	420	136	50	72	61.4
Pacific Northwest/Alaska	575	153	40	20	37.0
U. S. Total	13,157	3,611	987	195	36.3

1/ *Excludes treated discharge to ground and treated discharge to sewers*

INDUSTRIAL WASTEWATER COOLING REQUIREMENTS

Quite apart from waste treatment requirements, industry faces a considerable expenditure arising from the need to reduce the temperature of heated wastewater discharges. Cooling water intake of thermal electric power generating establishments in 1964 amounted to 41,938 billion gallons; and the largest category of water intake by manufacturers is that for cooling purposes, a reported 9,385 billion gallons in 1964 by users of 20 million gallons or more, over 70% of recorded water-use by manufacturers. Combined cooling water intakes of major manufacturing and power generating establishments averaged 142 billion gallons per day, or almost enough to equal the 146 billion gallons per day of estimated use by irrigation, the largest user of water. Since the rate of growth of demand for power and manufactured products is greater than that for agricultural products, industrial intake of cooling water today probably exceeds use of water by irrigation, even conceding the efficiencies possible in recycling of cooling water.[11]

Industrial cooling waters are a prime source of thermal pollution - the addition or removal of heat from a stream that causes water temperature to be above or below ambient temperature. They are not the only source of thermal pollution. Temperature changes can be induced by the presence of a dam, by depletion of a stream through diversion, by the warming of irrigation return waters that occurs on fields, by industrial process and municipal effluents whose temperature characteristics have been modified. Industrial cooling is, however, a very significant source of thermal pollution, and the one we are best equipped by information to evaluate and to remedy.

Temperature modification is a significant kind of pollution in itself. Warmed waters are intolerable to many desirable aquatic life forms, and their utility for cooling is diminished. Temperature modification also contributes to other forms of pollution. Warming of water accelerates most of the biological and chemical processes that occur in water, sometimes to an extent that affects the kind as well as the degree of water quality modifications. Thus the more rapid decomposition of dissolved organics that occurs in warmed water can result in oxygen depletion; and attainment of threshold temperature levels may effect reactions that cause otherwise tolerable concentrations of materials (e.g., of the sulfides of wood pulping) to become toxic to aquatic life.

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[11] *It should be noted, however, that both manufacturing and power generation are users throughout the year, and that their water use occurs principally in the humid northeastern U. S. In distinction, irrigation occurs mainly in arid western states and over less than half of the year. Total water quality impacts of irrigation, concentrated in time and place, might well be expected to exceed that of industrial cooling.*

Information on waste heat discharge or on thermal pollution is limited. Available data, primarily estimates of water intake and consumption by various use categories, are of limited accuracy. We may estimate, but we cannot know, the volume of water discharged and the gross increase in temperature that occurs.

Seasonal factors bear upon the validity of estimates. The amount of water used for cooling varies widely by season, due to the greater cooling efficiency of colder winter water. Similarly, the increased temperature of cooling water discharge has a less deleterious effect on receiving waters in winter.

Even the prevalence of thermal pollution is difficult to assess. Volume of water and heat transfer properties of a river basin provide no guide to the seriousness of a temperature problem, for thermal pollution may occur on individual streams or at stream points, yet be indistinguishable and unmeasurable above and below the affected areas. Nevertheless, it is generally recognized that heat is a significant pollutant, and the one most likely to increase in seriousness in the immediate future.

Cooling requirements can most advantageously be examined through the steam-electric generating industry, where data is readily available, heat exchange mechanisms may most conveniently be considered, an industrially homogenous sample is available, and, most significantly, where the preponderance of waste heat originates. The method followed in cost development was to attempt to deduce temperature stabilization requirements associated with thermal generation of power, and to infer cooling requirements for manufacturing from known relationships with waste heat of power plants.

A steam-electric generating plant consists of a boiler where water is heated to produce steam under pressure, a turbine where the expansion of the steam is converted to mechanical energy, which is in turn converted to electrical energy in a generator, a condenser which further increases the pressure difference through the turbine by converting steam to water, and a feed water pump which returns the condenser water to the boiler. Each plant has a cooling system to circulate water through the condensers. With once-through cooling - the cheapest and most convenient method if water is plentiful and protection of the environment against heat pollution is not a consideration - water is pumped from a source through the condenser and returned to the source stream; otherwise, the heated cooling water may be passed through a cooling device and recycled through the condenser, together with necessary additional make-up water. In the latter case, only blowdown is returned to the stream; and the thermal pollution probability is reduced or eliminated.

The path followed by water as it is converted to steam, expands, and is condensed back to water determines the efficiency with which thermal energy is converted first to mechanical energy and then to electrical energy. Inherent in the conversion is wasted discharge of a portion of the energy to the environment as heat. Efficiency of energy conversion is limited by the capability of boilers and turbines to withstand high temperatures for extended periods of time and of condensers to lower exhaust temperature. The higher the generating efficiency - expressed as net heat rate, or the amount of thermal energy required to produce a kilowatt-hour of electricity - the less heat that is wasted to cooling waters.

Advances in generating technology have reduced the amount of heat required to produce electricity. By increasing the size of plant, the temperature and pressure of steam, utilization of reheat cycles and heat transfer in boilers and condensers, preheating boiler feed with waste heat, and other operational improvements, utilities have effected a reduction in their average net heat rate from 25,000 Btu per kilowatt-hour in 1925 to 10,453 in 1965. Since one kilowatt-hour is the energy equivalent of 3,413 Btu, the increase in efficiency has meant a drop from 21,587 Btu to 7,040 Btu of heat that is wasted to the environment in the production of a kilowatt-hour of electricity. Obviously, it is to the interest of the generating industry to utilize heat as fully as possible, rather than wasting it. Unfortunately, we seem to be approaching the limits of the efficiency possible with present generating methods. Current best plant heat rates are just over 8,700 Btu; and informed opinion seems to hold that a net heat rate of 8,500 Btu represents the outer limit of efficiency in fossil-fueled steam-generation.

More significant, the gross mathematics of the situation have created a situation in which increased demand for power has more than compensated for increased efficiency. Electric power production in this country has doubled every 10 years during this century, and most of the increase has come through use of thermal-generating methods. The number of new plants has increased the total production of waste heat at a rate far in excess of that with which growing generating efficiency has reduced unit heat loss; where the net heat rate has declined at a 2.8% annual rate over the last 40 years, steam-electric power generation has increased at a 7.2% annual rate. And because each succeeding generation of power plants has been larger - one of the major reasons for their increase in efficiency - the discharge of heated cooling water at point locations has soared.

This may be best indicated by example. Nine new generating units, each with a net heat rate of 10,000 Btu/kw-hr or better, were brought on stream in 1965. The average rated capacity of these plants was 308 megawatts. In the five-year period that ended in 1965, no less than 72 generating units were retired. Heat rates of the retired units were in the 15,000 to 20,000 Btu/kw-hr range; and average capacity of the retired units was only 22 megawatts. Thus, in spite of an average efficiency a third to a half greater than the retired plants, new plants coming on stream in one year - because of their much greater size - contribute almost as much waste heat to the environment as total retirements over a five-year period. Because the wasted heat of the new facilities was concentrated at fewer points, potential effects on quality of receiving waters are even greater than a simple comparison of gross magnitude would indicate. (See Table II-21 below.)

TABLE II-21

WASTE HEAT - COMPARISON OF NEW GENERATING UNITS COMING ON STREAM IN 1965 WITH PLANT RETIREMENTS 1961-1965

	New Units 1965	Retirements 1961-1965
Number of Plants	9	72
Average Capacity (Megawatts)	308	22
Average Net Heat Rate (Btu/kw-hr)	10,000	17,500
Total Waste Heat (Btu/hr)	18,259,164	22,313,808
Average Waste Heat/Unit (Btu/hr)	2,028,796	309,914

If the plants used in the foregoing illustration are an accurate sample, the modern steam-generating plant is almost seven times as serious a potential source of water pollution as the 30 to 35-year old plant that it replaces.

In point of fact, however, the modern plant is an even more serious potential polluter than the illustration indicates. About half of the generating capacity currently scheduled to come on stream by 1975 will be nuclear-fueled, and the future predominance of nuclear over fossil-fueled plants seems to be an obvious fact. Current estimates are that half of the generating capacity that will become operational over the next decade will be nuclear; and the average size of nuclear plants is increasing as experience with their operation accumulates. We have noted that the average new plant coming on stream in 1965 had 308 megawatts of generating capacity. Presently scheduled (fall 1967) nuclear additions to capacity will, on average, be two or three times as large. Of the seven nuclear-fueled steam generating plants presently scheduled to go into service in 1975 and later, none will be of less than 800 megawatts, five will have a capacity of 1,000 megawatts or more. (Table II-22.)

The growth of nuclear power generation is significant in terms of pollutional effects, not just because of the great size of the units, but because of inherently lesser thermal efficiency and heat dissipation in the generating process. The net heat rate of nuclear plants in operation in 1965 averaged 11,680 Btu/kw-hr, 29% thermal efficiency. In distinction, the average efficiency for all steam generating plants was 32.6%, and the efficiency of the most efficient (fossil-fueled) plant was 39.1%. Where it is now generally assumed that the average efficiency of fossil-fueled generating plants may ultimately run into a ceiling near current "best plant" levels, expectations for thermal efficiency of the nuclear-fueled portion of the industry do not run much above the current average for the industry. Moreover, expenditure of heat through incomplete combustion and losses through the stacks - which mediate the cooling water requirements of fossil-fueled plants - will not be a factor in reducing cooling requirements imposed on water by nuclear plants. Thus, it will take more heat to generate a given amount of electrical energy in the nuclear plants of the future, and more of that heat will have to be dissipated into cooling waters.

We cannot depend on increasing thermal efficiency alone to protect our waters from heat pollution. Fortunately, there are a number of well-developed techniques of evaporative cooling which industry may apply to reduce temperature of cooling waters. Cooling ponds allow heat to pass from a water surface to the air immediately above. Spraying hot water into the pond or reservoir facilitates thermal exchange by allowing heat to pass from water droplets to air as well as from pond surface to air. Natural draft cooling towers - which operate by pumping water to the top of a structure, from whence it flows vertically downward, exposed to air which flows horizontally through louvers - provide heat exchange at the air/water interface. Mechanical draft cooling towers operate in the same fashion as natural draft towers, with the addition of fans to induce air movement through the tower. Substitutions of air or other coolants for water offer other methods of controlling thermal pollution which may, in the future or under specialized conditions, be applied.

It should be noted that the presence of facilities for stabilizing the temperature of cooling waters does much to relieve the generating - or other - industry from dependence on natural water supplies. There is little point to stabilizing the temperature of cooling water, then discharging it back to the water course and assuming the cost of pumping in a fresh supply. Once

TABLE II-22

NUCLEAR-FUELED GENERATING CAPACITY OPERATIONAL IN YEAR, 1957-1973

Period	Number of Plants	Average Rated Capacity (Megawatts)
1957-1967	18	161
1968	2	507
1969	5	654
1970	7	606
1971	15	830
1972	14	775
1973	13	864

Source: Atomic Energy Commission

cooled, the supply is again available for use, requiring only the addition of enough water to make up for loss through evaporation.

The build-up of dissolved solids in reused water that occurs as a result of continuous evaporation requires that the recirculated supply be exchanged for new cooling water at intervals. But total water requirements are significantly diminished by cooling facilities. To a very considerable extent, availability of cooling facilities mitigates the necessity of selecting a plant site near a considerably sized source of dependable water supply. Economies of location may, then, often compensate for at least a part of the cost of cooling.

The cost of a cooling facility depends on a number of factors whose combination varies from establishment to establishment. Where land is cheap and plentiful, a water supply dependable, and streamflow sufficient to assimilate a moderately heated volume of wastewater, once-through cooling with use of a simple pond might work well. Where water is scarce, mechanical draft cooling and recirculation may be not only most economic, but absolutely essential for operation. The size of the generating plant, its thermal efficiency, the allowable temperature of receiving waters, all have a power to modify cooling costs. Cooling efficiency, too, can be engineered into a plant. The more heat that is transmitted to a given volume of cooling water, the less water that is required for cooling purposes. Thus a plant that releases an effluent with a temperature 20° above influent temperatures will have to spend less money to construct a cooling tower than will a plant where cooling water temperature increases only 15°.

Plant efficiency, cooling requirements, land availability, and other elements will, then, affect the resolution of costs. But within the range of affective factors, a number of sources provide guides to generalized unit costs. The FPC's National Power Survey has provided the estimate that construction costs for contemporary fossil-fueled power plants are about five dollars per kilowatt-capacity greater with cooling towers than with once-through cooling. (By implication, the added cost would be about eight dollars per kilowatt-capacity for nuclear plants.) A consulting firm, EBASCO, has estimated that cooling towers would add four to 10 dollars per unit of capacity to the cost of nuclear-fueled power plants. The principal authority in the field is probably George O. G. Löf, who has indicated that costs of constructing cooling towers amount generally to eight dollars per kilowatt-capacity, while their operation adds about 0.5 mills per kilowatt-hour to the cost of electricity produced.

Recognizing that individual conditions have a great power to modify costs, it is possible to estimate the total cost of providing cooling to all thermal generating plants on the basis of recorded net heat rates and the use of a single cooling method. Such an estimate has been made.[12] Utilizing a design that assumed: (1) mechanical draft cooling towers, (2) an approach temperature of 10° F., (3) water temperature range of 10°, 15°, and 20° F., (4) $8.00 per gallon per minute average construction cost for cooling tower and appurtenances, and (5) summer ambient temperatures, it was calculated that to provide cooling towers for each of the 514 plants covered in the 1965 annual report of the Federal Power Commission would require an expenditure of:

(1) At an average cooling water temperature increase of 10°, $665 million,

(2) At an average cooling water temperature increase of 15°, $594 million,

(3) At an average cooling water temperature increase of 20°, $533 million.

While the figures indicate the general magnitude of the investment that would be required to provide absolute stabilization of temperature from existing steam-electric generating sources, some adjustments are required to make them specific for existing conditions. The plants evaluated - those covered by Steam-Electric Plant Construction Cost and Annual Production Expenses, 1965, the most recent volume of an annual series issued by the Federal Power Commission - account for 93% of thermal generating capacity in place in the pertinent year. Moreover, costs are those associated with a range of cooling efficiencies, while the average reported temperature increase of the cooling waters of documented generating plants in 1965 was 13° - suggesting a cost very near the top of the range. Inferring the cost associated with the 13° temperature increase ($620 million for the 514 plants) and extending it to all plants, including those not covered by the FPC report, provides a total cost for mechanical draft cooling towers of $705 million.

Some portion of the indicated investment is presently in place, largely in small plants, and almost entirely in plants located west of the Mississippi. It is very rare that coastal plants and those located on major river systems install cooling towers or other facilities. Until very recently, availability and dependability of a cooling water supply was a major consideration in determining the presence or absence of cooling facilities. Large plants tend to be located near abundant water supplies, and to be users of once-through cooling techniques. (Table II-23.)

Because locational considerations have played so large a part in determining the status of cooling facilities, an attempt was made to allocate regionally the $705 million requirement, and to estimate the current replacement value of cooling facilities in place on the basis of the percentage of regional

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[12] *Mathur, S. P., Thermal Pollution From Steam-Electric Generating Plants.*

TABLE II-23

REGIONAL DISTRIBUTION OF THERMAL GENERATING PLANTS AND COOLING FACILITIES, 1965

Region	No. of Plants	1,000 MW Generating Capacity	Plants With Cooling/Total Plants, By Capacity In Megawatts					
			100	101-200	201-400	401-600	601-900	900	Total
North Atlantic	101	33.7	1/11	0/26	0/35	0/14	0/13	0/2	1/101
Southeast	61	19.8	1/10	0/12	1/24	0/7	0/5	0/3	2/61
Great Lakes	54	21.1	0/11	0/8	0/12	0/11	0/7	0/5	0/54
Ohio	59	25.6	1/6	0/5	4/21	1/16	0/3	0/8	6/59
Tennessee	9	6.8	-	-	1/1	-	1/6	0/2	2/9
Upper Mississippi	49	10.7	1/18	1/13	0/11	0/4	0/2	0/1	2/49
Lower Mississippi	14	4.6	2/3	1/2	2/6	0/1	0/2	-	5/14
Missouri	33	5.2	9/17	1/7	2/6	2/3	-	-	14/33
Arkansas-White-Red	30	5.6	9/10	5/10	4/7	2/3	-	-	20/30
Western Gulf	51	14.3	6/10	12/13	12/17	4/6	2/5	-	36/51
Colorado/Great	22	3.8	5/7	9/10	4/4	-	1/1	-	19/22
California/Hawaii	31	14.1	2/5	3/5	2/7	1/5	0/2	1/7	9/31
Pacific Northwest/Alaska	-	-	-	-	-	-	-	-	-
Total	514	165.5	37/108	32/111	32/151	10/70	4/46	1/28	116/514

capacity associated with cooling facilities to total regional steam-electric generating capacity. The assessment, presented in Table II-24, indicates that only about $104 million of current replacement value of such facilities is provided - assuming that all facilities provide the required degree of stream protection.

Problems of cooling are far more complex in the case of manufacturing establishments than are those of the electric generating industry. Temperatures may be higher, permitting more economical heat dissipation, but contamination of heated wastewaters and generally smaller size of establishments tend to increase costs. Assuming equal costs per unit of heat dissipation, temperature control for the volume of waste discharge by manufacturers reported in the 1963 Census of Manufactures, "Water Use in Manufacturing", would require an investment on the order of $300 million. (Table II-25.) (It should be noted that the figure represents no more than an estimate - an expert estimate, it is true - of the relationships between manufacturers' wastewater discharge, steam-generating plant cooling costs, and manufacturers' wastewater characteristics. It is, in short, a highly informed guess.)

It is possible to allocate the estimated investment requirement for cooling facilities among industries, on the basis of their relative intake of cooling water. It is not feasible, however, to estimate accurately what portion of the total requirement is presently met in any industry, or to assess the effects of relative thermal and cooling efficiency. The allocation, then, must be recognized to be extremely general.

Because regional climate and hydrology have been the major operative elements in determining the prevalence of cooling and reuse of water for manufacturers as well as for power generating plants, it is not unreasonable to assume that the distribution of cooling facilities among regions is similar in manufacturing and production of electricity. If this is so, then the current level of investment in cooling by manufacturers is about $40 million, concentrated in southwestern states. (Table II-26.)

The need for cooling facilities may be expected to expand at a somewhat more rapid rate than that for waste treatment, the reason being that demand for electricity is expected to continue to increase at a more pronounced rate than demand for manufactured products. The dimensions of the projected cost increase will depend in large measure upon the prevalence of nuclear-fueled generating plants in the future. The indicated investment schedule presented in Table II-27 is based on the assumptions that: (1) the need for cooling facilities in the electric generating industry has increased at the same rate from 1965 through 1968 as has output of electricity, while the need for cooling facilities in manufacturing has increased at the same rate from 1964 to 1968 as has the output of manufactured goods, as measured by the Federal Reserve Board Index of production; (2) the ratio of cooling facilities required to cooling facilities provided is the same in 1968 as that estimated for the base year 1965 for electrical generating plants, and the base year 1964 for

TABLE II-24

COOLING FACILITIES REQUIRED, STEAM-ELECTRIC GENERATING, BY REGION, 1965

Region	Millions of 1968 Dollars		
	Investment Requirement	Investment Provided	Additional Investment Required
North Atlantic	143.1	0.1	143.0
Southeast	84.6	1.4	83.2
Great Lakes	89.5	-	89.5
Ohio	109.3	7.4	101.9
Tennessee	28.9	4.5	24.4
Upper Mississippi	45.8	.9	44.9
Lower Mississippi	19.7	2.4	17.3
Missouri	21.9	9.3	12.6
Arkansas-White-Red	24.0	14.6	9.4
Western Gulf	60.6	39.0	21.6
Colorado/Great	16.2	15.1	1.1
California/Hawaii	59.9	11.3	48.6
Pacific Northwest/Alaska	-	-	-
Total	703.5	104.0	599.5

TABLE II-25

MANUFACTURERS' CAPITAL REQUIREMENTS FOR COOLING FACILITIES, BY INDUSTRY, 1964

Industry	Cooling Water Intake (Billions of Gallons)	Percent of Total	Indicated Value of Required Cooling Facilities (Millions of 1968 Dollars)
Food & Kindred Products	392	4.2	12.6
Textile Mill Products	5	.1	-
Paper & Allied Products	607	6.5	19.5
Chemical & Allied Products	3,120	33.2	99.6
Petroleum & Coal Products	1,212	12.9	38.7
Rubber & Plastics	128	1.4	4.2
Primary Metals	3,387	36.1	108.3
Machinery, except electrical	111	1.2	3.6
Electrical Machinery	53	.6	1.8
Transportation Equipment	102	1.1	3.3
All Other	268	2.9	8.7
Total	9,385		300.0

manufactures; (3) the deficiency in cooling facilities will be made up in equal annual expenditures over the period 1969-1973; (4) the requirement for manufacturers' cooling facilities will increase at a 4.5% annual rate over the period 1969-1973 (the rate is based on a Department of Commerce projection for the industries whose waste treatment requirements were evaluated in an earlier portion of this section); (5) the cooling requirements for electrical power generation will increase at the 7.2% annual rate which has applied to output of electrical power in this century; (6) half of the increase in the cooling requirement of thermal-electric power generation will be nuclear, and that half will require the expenditure of 60% more for cooling facilities than an equal incremental addition to the conventional thermal generating component of the additional supply.*

The indicated investment requirement under this set of assumptions amounts to $1.6 billion over the five-year period. It may very safely be assumed that the figure represents an absolute maximum, since it is based on 1965 average thermal efficiency, and presumes complete application of cooling facilities throughout industry under conditions of rapidly expanding output. One might conjecture that actual requirements will prove to be considerably less, since the imposition of additional outlays of such magnitudes upon industrial investment requirements will almost certainly prove a powerful incentive to develop and apply techniques to increase cooling efficiency. (Such incentives might initially be expected to be operative in the case of manufacturing, since the protected rate structure and consequent earning power of utilities tends to insulate profits in considerable measure from the effects of cost-increasing developments.)

Methods to reduce cost of cooling heated discharges, or of limiting the extent of heated discharge, are numerous. This in itself argues for the probability of application of operational techniques to abate thermal pollution rather than reliance on a single method of water treatment and recycling. Least cost combinations of method are indicated whenever there is more than

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*Note: *"Problems of cooling supply faced in fossil plant design are substantially magnified in the case of nuclear extensions. Prompted by rapidly decreasing installed cost per kilowatt, nuclear unit ratings have escalated to the 1,000 megawatt range. In addition, current light water reactor cycles are not as efficient as are the modern supercritical reheat designs employed for fossil-fueled firing. For this reason, and because nuclear fuel firing does not involve inherent stack gas, or boiler losses, reactor station heat rejection to plant circulating water coolant is about 1-2/3 as great as it is for identically sized increments of fossil-fueled capacity." (P. 3, "Cooling Tower Solutions to Problems of Power Station Circulating Water System Design", Arthur J. Fiehn, ASCE, New York, October 1967.)*

TABLE II-26

REGIONAL DISTRIBUTION OF COOLING FACILITIES REQUIREMENTS IN MANUFACTURING, 1964

Region	Millions of 1968 Dollars		
	Facilities Required	Facilities Provided	Investment Deficiency
North Atlantic	62.7	.1	62.6
Southeast	16.2	.3	15.9
Great Lakes	51.0	-	51.0
Ohio	67.2	4.6	62.6
Tennessee	10.5	1.6	8.9
Upper Mississippi	11.7	.2	11.5
Lower Mississippi	16.8	2.0	14.8
Missouri	2.7	1.1	1.6
Arkansas-White-Red	2.4	1.5	.9
Western Gulf	49.5	31.9	17.6
Colorado/Great	.9	.8	.1
California/Hawaii	2.1	.4	1.7
Pacific Northwest/Alaska	6.3	-	6.3
Total	300.0	44.5	255.5

TABLE II-27

INDICATED ANNUAL INVESTMENT REQUIRED TO PROVIDE COMPLETE COOLING FOR MAJOR INDUSTRIAL ESTABLISHMENTS BY 1973

	Millions of 1968 Dollars		
	Manufacturing	Thermal Power	Total
Projected Value of 1968 Cooling Required	350.5	866.7	1,217.2
Projected Value of Facilities Available	51.9	128.3	180.2
Indicated Deficiency	298.6	738.4	1,037.0
Annual Investment Required:			
1969	75.6	228.8	304.4
1970	76.2	234.5	310.7
1971	76.9	240.8	317.7
1972	77.7	247.5	325.2
1973	78.5	254.6	333.1
Total Investment, 1969-1973	384.9	1,206.2	1,591.1

one way to derive a desired result. The need for such development is exemplified in a research report issued by the Pacific Northwest Laboratories of Battelle Memorial Institute with respect to Nuclear Power Plant Siting in the Pacific Northwest that concluded that "the method of handling waste heat was the single most important economic variable" affecting power plant location. Once-through cooling with fresh water was estimated to involve an investment per kilowatt of capacity of $3 less than once-through cooling with salt water, and $10 per kilowatt less than use of cooling towers. Power could be produced with once-through fresh water cooling at a total cost of 3.0289 mills per kilowatt-hour, compared to 3.1603 mills with cooling towers and 3.1069 mills with cooling ponds. Obviously, the potential significance of the one factor indicates the necessity for deriving lower cost techniques for dealing with it.

As with other pollution controlling costs, development of technologies that incorporate desirable features would appear to provide the optimum long-term approach to control. Utilization of waste heat, through further reduction in the net heat rate or by transferring waste heat to other processes, will become increasingly economic, even with utilization of relatively high cost procedures, as pressures to assume the cost of controlling heated discharges make once-through cooling an unacceptable procedure in a growing number of cases.

Site selection, too, should increasingly reflect temperature control considerations. By increasing the cost of once-through cooling, pollution control needs have extended the number of locations which, on a total cost basis, are economically acceptable. Certainly any plant that elects in the future to choose a site in which once-through cooling is acceptable under normal hydrologic and climatic conditions, must realize with it the potential requirement to reduce or eliminate operations during periods when conditions make it impossible to discharge heated waters without damage to the aquatic environment.

Many design or operating techniques can limit cooling costs. Outfalls that facilitate mixing of heated discharges with normal flows, and do not result in increases in temperature beyond that allowed by water quality standards, are one such possibility. Another is an outfall design that results in temperature stratification in a thin upper layer of the receiving stream, which, in effect, becomes an extended cooling pond. It has been proposed, too, that nuclear power plants be sited so that their cooling water discharges may be utilized for irrigation rather than returned directly to the stream. The warmed waters are thought to facilitate plant growth; and during the cold season when irrigation is not practiced, discharge of heated waters is not generally harmful to aquatic life. An ambitious proposal in connection with a planned nuclear generating plant in the Pacific Northwest would have cooling water taken from one watershed, pumped up over a low range of mountains during the summer for discharge in another watershed which suffers naturally from high temperature, due to depleted summer streamflows. The net result would be to eliminate heated discharges to the source stream, and improve stream flow and quality in the receiving stream. Use of air cooling, currently two to three times as expensive as evaporative cooling, would conserve water and allow reuse, if less costly designs could be developed. Improvements in cooling tower design, too, may be expected to result imminently from the pressure of temperature regulating requirements.

What we have defined, then, is the maximum expectable cost of controlling thermal pollution over the next five years. Technological improvements and management techniques should be able to reduce such costs.

Certainly it is desirable that every cost-reducing effort that is compatible with maintenance of water quality standards be utilized, for the sums involved in temperature stabilization are potentially huge. This is particularly true in assessing cost implications of an extended time frame. Because of the high demonstrated rate of increase in utilization of electrical energy, the cost of cooling, if provided through methods no more efficient than complete utilization of mechanical draft cooling towers, would within several decades exceed the cost of all other forms of wastewater treatment. Indeed, accomplishment of complete cooling for the levels of manufacturing output and electrical generation projected in this study would bring total annual outlays very close to $700 million by 1973.

Table II-28, which projects cash outlays for cooling for the five-year period, 1969-1973, rests on the assumption that mechanical draft cooling towers are provided for all steam-electric generating plants and all manufacturing plants using 20 million gallons or more of water per year. Replacement costs, as measured by depreciation, are assumed to be incurred at rates which reflect the generalized depreciation practice of manufacturing firms and the 30-year average life of steam-generating plants. Operating and maintenance costs are assessed on the basis of a cooling tower charge of .14 mills per kilowatt-hour for steam-generating plants; and the assumption that the relationship between operating and maintenance costs in manufacturing and in power generating are similar to the relationship between their respective capital investments in cooling towers.

TABLE II-28

ANNUAL CASH OUTLAYS FOR COOLING
1969-1973

Source of Outlay	Millions of 1968 Dollars					
	1969	1970	1971	1972	1973	5-Year Total
New Plant Required:						
Steam-generating	228.8	234.5	240.8	247.5	254.6	1,206.2
Manufacturing	75.6	76.2	76.9	77.7	78.5	384.9
Depreciation/Replacement:						
Steam-generating @ 3.5%	12.5	20.7	29.1	37.8	46.7	146.8
Manufacturing @ 5%	6.4	10.2	14.0	17.9	21.8	70.3
Total Capital Outlays:						
Steam-generating	241.3	255.2	269.9	285.3	301.3	1,353.0
Manufacturing	82.0	86.4	90.9	95.6	100.3	455.2
Operating and Maintenance:						
Steam-generating	58.0	94.8	132.4	170.9	210.3	666.4
Manufacturing	20.7	32.6	44.8	56.7	68.8	223.4
Total Cash Outlays	402.0	469.0	537.8	608.5	680.7	2,698.0
Current Replacement Value of Installed Plant:						
Steam-generating	357.1	591.6	832.4	1,079.9	1,334.5	
Manufacturing	127.5	203.7	280.6	358.3	436.8	

CONCLUSIONS

Review of the volume of industrial wastes discharged to water and of the costs associated with controlling their polluting effects provides some conclusions which may be useful guides in pursuing the attainment of water quality standards. In particular, it would appear that greater relative attention to industrial wastes would have the effect of accelerating progress toward meeting water quality standards, yet would require lower initial investments in waste controlling facilities than are demanded by current emphasis on municipal waste treatment. This is felt to be true because:

(1) Manufacturing activities are the largest measurable and controllable sources of biochemical oxygen demand, heat, and of settleable and suspended solids discharged to the nation's waterways. Wastes from manufacturing are particularly concentrated in the northeastern quarter of the nation - the area which has suffered most markedly from water pollution - and are overwhelmingly associated with the chemical, pulp and paper, food processing, steam-electric power generating, and steel industries. These sources of waste and heat, then, might well be made the major foci of program and research attention.

(2) There are a variety of techniques for controlling industrial waste discharges, these being for the most part applications or adaptions of the methods used to treat sanitary sewage. It is possible, then, to design and construct waste treatment plants capable of treating wastes from both industrial and municipal sources. Significant reductions - and in some cases near-complete elimination - of waterborne industrial wastes may also be provided through modifications of manufacturing processes. Attention may fruitfully be devoted to development of incentives and engineering systems that result in optimum waste reduction/cost relationships.

(3) In general, unit construction costs are less for industrial waste treatment plants than for municipal waste treatment plants scaled to handle an equivalent waste loading or hydraulic volume, and the cost advantage extends to municipal systems handling a large component of industrial wastes. Moreover, unit costs tend to decrease sharply with an increase in the volume of wastes to be handled. It would appear that there are compelling cost advantages in cooperative waste treatment arrangements that involve handling of the wastes from a variety of sources in large municipal or metropolitan waste treatment works.

(4) It is estimated that facilities sufficient to provide the equivalent of secondary waste treatment for all major water-using manufacturing establishments would be provided by an investment of $4 billion to $5 billion. Indications are that a quarter to a half of that investment requirement had not been met by the summer of 1967. Moreover, when conditions require higher than secondary levels of waste treatment efficiency, construction costs increase far more than proportionately. It is clear, then, that considerable investment in waste treatment facilities - or in process modifications which reduce wastes - remains to be made by American manufacturing.

(5) The principal impact of the waste treatment requirement on manufacturers' costs will occur through routine and continuing operating and maintenance charges rather than in the form of construction costs. Over the next five years, manufacturers must expend over a billion dollars a year - the amount rising with the growth of output and level of treatment facilities in place - in order to adequately discharge waste treatment requirements. About three quarters of the total cash outlays will arise out of normal operating needs rather than as a result of new investments or depreciation. Industrial planning and research, then, might well be directed to development of more economically operated waste treatment plants; and regulatory attention may often best be directed to monitoring the level of efficiency at which industrial waste treatment facilities are being operated, since their under-operation offers a convenient method of reducing production costs.

(6) Cooling of the heated wastewaters of manufacturing and power generation will require additional large investments. While there are a number of techniques that may be applied to handle the polluting effects of waste heat, it is estimated that universal use of mechanical draft cooling towers by steam-generating plants and major manufacturing plants would require $1.2 billion of facilities under current conditions, and that about $1 billion of that investment remains to be made. Thermal pollution is coming to be of increasing significance because of the rapid rate of increase of steam-electric power generation. In particular, the growing prevalence of very large nuclear-fueled power plants constitutes a distinct threat to water quality. Because of the limited current availability of wastewater cooling facilities and the rapid rate of expansion projected for sources of waste heat, cash outlays for cooling must increase at a particularly sharp rate if thermal pollution of

water is to be ended within five years. It is estimated that about $1.8 billion of cooling facilities must be in place by 1973 - by which time annual operating and maintenance costs for such facilities would approach $300 million per year - if all major industrial sources of waste heat were to be equipped with mechanical draft cooling towers. The magnitude of the investment requirement indicates that development of effective means of non-polluting heat dissipation should receive a high priority in research and development programs; while the rapid rate of growth of heat sources suggests that greater attention must be given to temperature control if the problem of thermal pollution is not to become a major one in the near future.

APPENDIX I

EFFECT OF POTENTIAL COST INCREASES

A constant price level - July 1967 dollars - was assumed in developing the cost of industrial waste treatment. Construction costs have been rising rapidly throughout the post-war period, however; and it would seem appropriate that the indicated values be reviewed in a format that accommodates the probability of price increases. (Figure II-A.)

Exactness in assessment of the impacts of future events is, of course, not attainable. The effects of increases in cost due to changes in price level or interest structures depend on the direction and degree of change and upon their distribution in time. We can, however, impose upon our static model some of the kinds of changes that have occurred in the past, in order to gage, in a general fashion, the results of a repetition or continuation of such influences.

Construction costs are weighed and reported regularly by Engineering News Record, whose "Index of Construction Costs" was applied generally in developing the report. The index has recorded a constant rise in construction costs through the period since World War II. Over time, the steepness of costs' ascending slope was progressively moderated until recently, when it began again to turn sharply upward. For the purposes of this analysis, a 3.6% annual rate of increase in the cost of construction has been presumed to apply over the next five years, that being the rate that characterized both the recent period from FY 1965 to FY 1968 and the decade that began in FY 1958. (Table II-A.)

The most obvious effect of an increase in construction costs will be exercised on annual investments to install waste treating facilities. If a 3.6% annual rate of increase is applied to the construction schedules presented in Tables II-14 and II-27, treatment plant construction costs are calculated to escalate in the amount of $400 million to $600 million over the five-year period, 1969-1973 (Table II-B). Constructing required waste treatment facilities would involve the expenditure of $2 billion of current dollars rather than $1.8 billion of constant dollars if the estimate of deficiency based on the Industrial Waste Profiles is used, $4 billion rather than $3.6 billion if the projection of census data is used to define the treatment deficiency. Estimated cooling facilities construction costs would escalate over the five-year period from the estimate of $1.6 billion to almost $1.9 billion.

The five-year temporal matrix cannot adequately reflect the impact of increasing construction costs on capital requirements. The most damaging results of rising cost occur cumulatively and over the long term, in the form

FIGURE II - A
ENGINEERING NEWS-RECORD CONSTRUCTION COST INDEX,
(1913 TO 1967) PROJECTED TO 1973

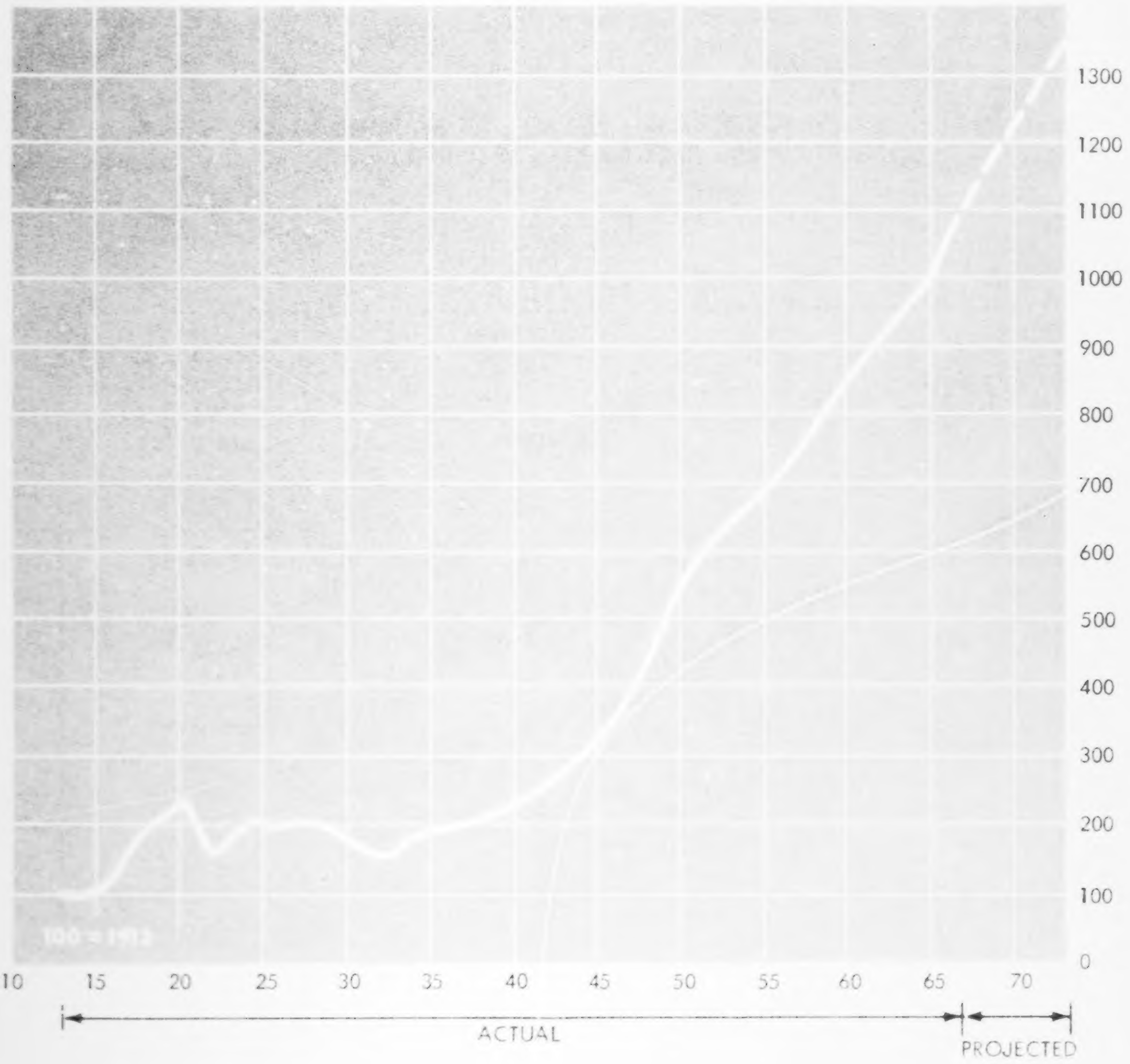

TABLE II-A

CONSTRUCTION COST INCREASE, AS MEASURED BY THE ENGINEERING NEWS RECORD INDEX

Date (Federal Fiscal Year)	ENR Index	Annual Rate of Increase From Period to July 1967
1945	308	5.4%
1950	510	4.3%
1955	660	3.9%
1960	829	3.4%
1965	977	3.6%
1968	1,085	-

TABLE II-B

EFFECT ON INVESTMENT REQUIREMENTS OF CONTINUING THE CURRENT (1958-1968) RATE OF INCREASE IN CONSTRUCTION COSTS

Year	Cost Increase in Millions of Current Dollars, By Year			
	Waste Treatment		Cooling	
	By Census Projection	By Estimate	Manufacturing	Thermal Power
1969	24.4	11.8	2.7	8.2
1970	51.7	25.7	5.6	17.2
1971	81.9	41.6	8.9	26.9
1972	112.5	57.5	11.8	37.6
1973	143.7	73.7	15.2	49.2
Total	414.2	210.3	44.2	139.1

Total Cost Increase Over Period:
By Census Projection - $597.5 Million
By Estimate - $393.6 Million

of constant pressure on cash flow. Facilities whose costs rise at a compounding rate cannot be replaced out of depreciation charges which are assessed at constant rates. If 1968's hundred-thousand-dollar waste treatment plant is to be replaced at the end of 20 years during which costs rise at a 3.6% rate, it will require almost $203,000 to install the new facility.

The effects of this penalty may be assessed over the limited time span utilized in the study. A 3.6% annual rate of increase in cost applied to the previously utilized investment schedules and to progressively revalue facilities in-place allows a comparison of constant and inflated values. (Table II-C.) Application of appropriate depreciation rates to both estimated book value and current replacement value indicates something of the deficiency of normal depreciation charges to meet replacement requirements. It should be noted, however, that the deficiency is, of necessity, considerably understated, due to the built-in revaluation of value of plant in-place in 1968 that occurs because it is expressed as 1968 current replacement value.

Under the comparison, depreciation charges over the five-year period, assuming current replacement value for plant in-place in 1968 and year-by-year additions to plant in projected current dollars, fall about $90 million short of meeting replacement needs. (Table II-D.) More significant than the gross amount, however, is the fact that the deficiency increases with time. In 1969, estimated depreciation charges are $3.3 million to $4.1 million short of replacement needs. By 1973, the deficiency expands to $34.5 million to $37.1 million. (The method distorts the degree of growth, since 1969 depreciation charges based on current replacement value of plant in-place in 1968 must be assumed to be estimated at levels well in excess of industry's actual rate of accrual. Nevertheless, the principle of expanding cash flow deficiencies holds true. With continuing persistence of inflation and an increasing total value of waste treatment plant in-place, the gap between cash flow from depreciation and actual replacement needs will become increasingly greater as time passes.)

While the effects of cost increases are most immediately evident and can most conveniently be analyzed in connection with construction costs, it must not be supposed that construction costs rise independently. The economic environment that results in higher construction costs must be supposed to be one in which operating costs, too, rise.

Unfortunately, we know too little about the elements of the costs of operating and maintaining industrial waste treatment plants to be able to project the effects of price increases upon them as precisely as in the case of capital cost factors. It must be assumed, for example, that a portion of the increase in costs of construction may be attributed to building into facilities some substitution of capital for labor or other cost elements; thus higher capital costs may be due partially to facilities which reduce operating outlays.

TABLE II-C

VALUE OF PLANT IN-PLACE, 1973, UNDER ALTERNATIVE EVALUATION PROCEDURES

	Millions of Dollars		
	Value in 1968 Dollars	Value By Cost of Construction	Replacement Value
Industrial Waste Treatment:			
By Estimate	4,026.0	4,236.3	4,789.8
By Projection	5,349.8	5,764.0	6,356.5
Industrial Cooling:			
Manufacturing Plants	436.8	481.0	521.5
Steam-generating	1,334.5	1,473.6	1,592.2

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TABLE II-D

CASH FLOW DEFICIENCIES ASSOCIATED WITH CONTINUING THE CURRENT RATE OF INCREASE IN CONSTRUCTION COSTS

(Millions of Dollars)

Year	Depreciation Charges in Current Dollars				Replacement Requirements in Current Dollars			
	Waste Treatment		Cooling		Waste Treatment		Cooling	
	By Estimate	By Projection	Manufacturing	Steam Power	By Estimate	By Projection	Manufacturing	Steam Power
1969	127.8	122.7	6.5	12.8	131.7	125.8	6.6	12.9
1970	146.6	160.6	10.6	21.6	155.3	168.2	10.9	22.2
1971	167.3	201.2	14.9	31.0	181.6	215.0	15.6	32.4
1972	188.4	242.5	19.2	40.6	209.2	264.0	20.5	43.2
1973	211.1	286.8	23.9	51.3	239.5	317.8	25.9	55.4
Total	841.2	1,013.8	75.1	157.3	917.3	1,090.8	79.5	166.1

Cumulative Deficiency in Cash Flow:
Five-Year Depreciation, by Estimate - $1,073.6 Million
Five-Year Replacement Requirements - $1,162.9 Million
Deficiency, By Estimate - $ 89.3 Million

Five-Year Depreciation, By Projection - $1,246.2 Million
Five-Year Replacement Requirements - $1,336.4 Million
Deficiency, By Census Projection - $ 90.2 Million

Lacking a definition of elements that compose operating and maintenance costs in industrial waste treatment, we may, for analytical purposes, fall back upon analogy for standards of evaluation. Waste treatment is basically a continuous flow renovation process, not unlike many industrial processes in its elements. It may be anticipated, then, that increased costs will be reflected in much the same degree in treating industry's wastes as in other portions of industry's activities. If this is so, then the pressure of inflation and other cost-increasing factors should be manifested in approximately the same dimensions as they occur and are measured and recorded by the Bureau of Labor Statistics "Index of Unit Production Costs." Over the past decade, labor and non-labor unit costs of production have been increasing at almost exactly the same rate, 1.8% a year. If the rate of increase continues unchanged over the five-year period of study, and is mirrored in the cost of operating and maintaining industrial waste treatment facilities, then wastewater facilities operating costs for the period will be about a quarter of a billion dollars greater than those measured in current dollars. (Table II-E.)

TABLE II-E

EFFECT ON OPERATING AND MAINTENANCE CHARGES OF CONTINUING THE CURRENT (1958-1967) RATE OF INCREASE IN COST

Year	Cost Increase in Millions of Current Dollars, By Year			
	Waste Treatment		Cooling	
	By Census Projection	By Estimate	Manufacturing	Thermal Power
1969	8.2	8.7	.4	1.0
1970	20.5	19.7	1.2	3.4
1971	37.4	33.3	2.5	7.3
1972	59.4	49.4	4.2	12.6
1973	86.0	68.2	6.4	19.6
Total	211.5	179.3	14.7	43.9

Total Cost Increase Over Period:
By Census Projection - $270.1 Million
By Estimate - $237.9 Million

SUMMARY

Maintenance of indicated current rates of increase in costs of construction and operation would expand outlays needed to provide proposed industrial wastewater treatment by $700 million to $1 billion over the next five years.

The figure is not presented as a prediction, but as an illustration of the impact of existing trends on the schedule of investments developed in the body of the study.

While the initial force of cost increases would occur in the area of capital investments, due to the current deficiency in industrial wastewater treatment, long-term effects on operating charges and supplemental outlays for replacement may be presumed to be highly significant. (Table II-F.)

TABLE II-F

SUMMARY OF TOTAL IMPACT OF PROJECTED COST INCREASES, 1969-1973

I - By Census Projection

Cost Element	Millions of Dollars		
	Cumulative Five-Year Cost Constant Dollars	Projected Incremental Charges	Cumulative Projected Current Dollar Cost
Industrial Waste Treatment:			
Construction of Plant	3,597.5	414.2	4,011.7
Replacement	1,013.8	77.0	1,090.8
Operating and Maintenance	3,422.9	211.5	3,634.4
Industrial Cooling:			
Construction of Plant	384.9	44.2	429.1
Replacement	75.1	4.4	79.5
Operating and Maintenance	223.4	14.7	238.1
Electric-Power Cooling:			
Construction of Plant	1,206.2	139.1	1,345.3
Replacement	157.3	8.8	166.1
Operating and Maintenance	666.4	43.9	710.3
TOTAL	10,747.5	957.8	11,705.3

II - By Estimate

Industrial Waste Treatment:			
Construction of Plant	1,810.7	210.3	2,021.0
Replacement	841.2	76.1	917.3
Operating and Maintenance	3,032.7	179.3	3,212.0
TOTAL (including cooling costs)	8,397.9	720.8	9,118.7

APPENDIX II

PROCEDURE FOLLOWED IN DEVELOPMENT OF THE WASTE TREATMENT COST MODEL

The summary steps performed in the costing method is presented below. The analysis consisted of repetitive calculation of sub-processes involved in eight steps for each of 20 major industrial groups. The steps were, sequentially:

(1) Classification of industrial waste sources by 11 industrial sectors and nine major sub-sectors;

(2) Definition of the average daily discharge by size of plant for the average small plant (intake of 20 to 99 million gallons of water in 1964) and the average large plant (intake of 100 million gallons or more in 1964) for each industrial classification;

(3) For each large plant class and each small plant class, calculation of average daily discharge, average daily discharge of process water, and average daily generation of BOD;

(4) Determination for the appropriate discharge and BOD classifications of each size of establishment of the cost of constructing a plant to treat: (a) the total discharge, (b) the discharge of process waters, and (c) the population equivalent of BOD. The arithmetic average of the three costs was then used as the design cost for plants in that industrial group and multiplied by the number of plants in each size class to obtain the imputed value of the 1964 waste treatment requirement for the industry;[13]

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[13] The implied assumption regarding the interaction of hydraulic loading, opportunities for segregation and advanced water using techniques, and waste concentrations is admittedly the weakest part of the analysis. It was built into the analysis to accommodate the minority of technical experts who expressed the opinion that industrial waste treatment is extraordinarily complex and costly when compared to municipal waste treatment. The analyst's opinion is that the cost would be more truly expressed - and at least a third lower - if based entirely on volume of process water and BOD concentrations. Indeed, accommodation of values developed in Industrial Waste Profiles produced a total investment requirement 30% below that achieved by the process described (CF pp. 58-60).

(5) Adjustment of the gross value figure to account for the level of existing treatment by: (a) deducting a percentage of the gross value equal to the percentage of flow discharged to public sewers (on the assumption that this portion of the industrial waste is or will be adequately treated by municipalities); (b) deducting from the total value a percentage of that value equal to the proportion of the industrial discharge that is made to the ground (on the assumption that ground discharge constitutes adequate treatment); and (c) deducting from the total value an amount equal to the portion of the industrial flow to surface waters that is treated, multiplied by the percentage that secondary waste treatment plants operated in that industry constitute of all its waste treatment plants. The net figure obtained is assumed to represent the value of the deficiency in industrial waste treatment in 1964;

(6) Projection of requirements to June 1968, by relating total value of treatment requirements associated with 1964 levels of production to projected outputs, and projecting growth of treatment by extending observed 1959-1964 shifts in relationships between output, discharge, volume of treated discharge to ground or to municipal sewers through the period, 1964-1968;

Addition of the increase in the value of treatment requirements between 1964 and 1968 to 1964 treatment requirements is assumed to represent the total value of required waste treatment in June 1968. The combination of all values is assumed to express the values associated with the current unmet industrial waste treatment requirement;

(7) Subsequent modification of the derived values to incorporate the estimates of replacement value of plant in-place and of total requirements developed in Industrial Waste Profiles prepared by contractors for 10 industries; unprofiled industry costs were reallocated to reflect the information contained in the profiles on the basis of the relationships developed by the analysis of census data; and

(8) Apportionment of the amounts derived for gross value of industrial waste treatment requirements among major drainage basins according to each region's proportionate share of the discharge of specific reported industrial sectors. The remaining, unaccounted-for portion of the values was distributed among regions according to their percentage of the total unaccounted-for industrial discharge, expressed as an exponential value of "all other manufacturing".

APPENDIX III

BIBLIOGRAPHY

Ambrose, T. W. and E. R. Castle. "Wastes From Potato Starch Plants." Industrial and Engineering Chemistry, June 1965.

Anderson. V. A Tentative Approach to the Establishment of Engineering Guide Lines in the Design of Treatment Facilities for Wastes Associated With the Manufacture of Food Products From Potatoes. Idaho Department of Health, Boise, Idaho.

An Assessment of Thermal Pollution Problems. Report of a Task Force appointed by the Science Advisor to provide recommendations for research and appropriate action. Washington, D. C. July 28, 1966.

Barnes, G. E. and L. W. Weinberger. "Internal Housekeeping Cuts Waste Treatment at Pickle Packing Plants." Wastes Engineering. January 1958.

Battelle-Northwest. Nuclear Power Plant Siting in the Pacific Northwest. Bonneville Power Administration. Portland, Oregon. July 1967.

Bender, R. J. Steam Generation. (A Power Special Report.) New York. June 1964.

Bendixen, T. W., R. D. Hill, F. T. Du Byne, and G. G. Robeck. "Cannery Waste Treatment by Spray Irrigation-Runoff." Cincinnati, Ohio. FWPCA. June 1967.

Berger, H. F. "Evaluation of Water Reclamation Against Rising Costs of Water and Effluent Treatment." TAPPI. August 1966.

Besselievre, E. B. "Pontiac Motors Treats Its Wastes." Wastes Engineering.

Black, H. H. Industrial Waste Treatment, as Varied as Industry. (Reprint from Civil Engineering for October 1955.) Cincinnati, Ohio. 1956.

Black, H. H. and G. N. McDermott. "Industrial Waste Guide-Beet Sugar." Proceedings of American Society of Civil Engineers, Journal of the Sanitary Engineering Division. February 1952.

Bolduc, E. J. Results of NCSI Industry Survey of Investment and Cost of Effluent Treatment. National Council for Stream Improvement.

Bower, B. *Industry and the Water Environment: A Study of Water Utilization Patterns in Selected Industries in Relation to Technologic and Economic Factors*. University of New Mexico, Albuquerque, New Mexico. May 1963.

Bower, B. T. "Incorporate Wastewater Handling in Plant Design." *Canner/ Packer*. February 1967.

Bodenheimer, V. B. "Factors to Consider in Waste Treatment Systems Evaluation." *Pulp and Paper Manufacturer*. February 1967.

Bradakis, H. L. "A Joint Municipal-Industrial Spray Irrigation Project." *Industrial Water and Wastes*. July-August 1961.

________. "Largest Activated Sludge Plant for Pulp and Paper Wastes Will Treat Sewage From Three Towns." *Wastes Engineering*. May 1960.

Bramer, H. C. "Economics and Water Pollution Abatement." *Water and Sewage Works*. February 1966.

Bryan, E. H. "Two-State Biological Waste Treatment." *Industrial Water and Wastes*. January-February 1963.

California Department of Water Resources. *Water Use By Manufacturing Industries in California, 1957-1959*. Sacramento, California. April 1964.

Caster, A. D. "The Municipality Looks at Industrial Wastes." *Industrial Water and Wastes*, July-August 1962.

Cawley, W. A. and V. A. Minch. "The Treatment of Pulp and Paper Mill Wastes." *Industrial Water and Wastes*. March-April 1963.

Columbia River Basin Project, FWPCA. *Snake River Basin, Comprehensive Report*. (In open file, FWPCA, Portland, Oregon, Washington, D. C.)

________. *Water Temperature - Influences, Effects, and Control*. Proceedings of the Twelfth Pacific Northwest Symposium on Water Pollution Research. Corvallis, Oregon. November 7, 1963.

Cootner, P. H. and G. O. G. Löf. *Water Demand for Steam-Electric Generation*. Resources for the Future. Washington, D. C. 1965.

Coughlin, R. L. "Alternatives and Costs to Achieve 5 P.P.M. Dissolved Oxygen in Portland Harbor." FWPCA. 1966. (Three memoranda in open file, Portland, Oregon.)

________. *Computed Waste Treatment Costs Related to Puget Sound Pulp Mills*. FWPCA. 1965. (In open file, Portland, Oregon.)

Culp, G. L. Soybean Processing and Related Wastes. U.S.P.H.S. Cincinnati, Ohio. January 1963.

Eckenfelder, W. A. Effluent Quality and Treatment Economics for Industrial Wastewaters. Austin, Texas. October 1967.

________. "Theory of Biological Treatment of Trade Wastes." Journal of the Water Pollution Control Federation. February 1967.

Edison Electric Institute. Historical Statistics of the Electric Utility Industry. 1962.

Eichberger, Willis. G. Industrial Water Use. U.S.P.H.S. Washington, D. C. February 1965.

Elonka, Steve. Cooling Towers. (A Power Special Report.) New York, New York. 1963.

Engineering News Record. Cost Indexes. "ENR 20-Cities, Construction Cost."

Fair, G. M. "Economies in Metal-Finishing Wastes Management." Proceedings of American Society of Civil Engineers, Journal of the Sanitary Engineering Division. January 1960.

Fair, G. M. and J. C. Geyer. Water Supply and Wastewater Disposal. John Wiley and Sons, Inc. New York, New York. April 1963.

Fairall, J. M. "Industrial Waste Treatment." Presented at the New Jersey Water Resources Conference, Rutgers University. July 12, 1966.

Federal Power Commission. Annual Production Expenses. Washington, D. C. Annually.

________. Steam-Electric Plant Construction Cost. Washington, D. C. Annually.

________. National Power Survey - 1964. Washington, D. C. 1964.

Fiehn, A. V. Cooling Tower Solutions to Problems of Power Station Circulating Water System Design. ASCE. New York, New York. October 1967.

Force, S. L. Beet Sugar Factory Wastes and Their Treatment, Primarily the Findlay System. Great Western Suguar Company. Denver, Colorado.

Formo, H. G. Problems and Approaches in the Treatment of Wastes From Potato Processing Plants. Idaho Department of Health. Boise, Idaho. May 1961.

Fullen, W. J. and K. V. Hill. "The Economics of Poor Housekeeping in the Meat-Packing Industry." *Journal of the Water Pollution Control Federation*. April 1967.

FWPCA, Applications for Research and Development Grants. (In open file, Washington, D. C. 1966-1967.)

________. *The Beet Sugar Industry - The Water Pollution Problem and Status of Waste Abatement and Treatment*. South Platte River Basin Project. Denver, Colorado. June 1967.

________. *An Industrial Waste Guide to the Cane Sugar Industry*. Government Printing Office. 1959.

________. *An Industrial Waste Guide to the Fruit Processing Industry*. Government Printing Office. 1962.

________. *An Industrial Waste Guide to the Meat Industry*. Government Printing Office. 1954.

________. *An Industrial Waste Guide to the Milk Processing Industry*. Government Printing Office. 1962.

________. *An Industrial Waste Guide to the Potato Chip Industry*. Government Printing Office. 1961.

________. Kansas City Regional Office. *Sewage Treatment Construction, Operation and Maintenance Costs, For Meat Packing Plants*. (In open file). Kansas City, Missouri. June 1967.

________. Technical Services Program. *Temperature and Aquatic Life*. August 1, 1967 (Internal Report).

________. Technical Advisory and Investigations Branch. *Temperature and Aquatic Life*. Cincinnati, Ohio. December 1967.

________. *Industrial Waste Profile No. 1 - Blast Furnaces and Steel Mills*. Washington, D. C. January 1968.

________. *Industrial Waste Profile No. 2 - Motor Vehicles and Parts*. Washington, D. C. January 1968.

________. *Industrial Waste Profile No. 3 - Paper Mills, Except Building*. Washington, D. C. January 1968.

________. *Industrial Waste Profile No. 4 - Textile Mill Products*. Washington, D. C. January 1968.

________. *Industrial Waste Profile No. 5 - Petroleum Refining*. Washington, D. C. January 1968.

________. *Industrial Waste Profile No. 6 - Canned Fruits and Vegetables*. Washington, D. C. January 1968.

________. *Industrial Waste Profile No. 7 - Leather Tanning and Finishing*. Washington, D. C. January 1968.

________. *Industrial Waste Profile No. 8 - Meat Products*. Washington, D. C. January 1968.

________. *Industrial Waste Profile No. 9 - Dairies*. Washington, D. C. January 1968.

________. *Industrial Waste Profile No. 10 - Plastics Materials and Resins*. Washington, D. C. January 1968.

Gehm, H. W. "The Activated Sludge Process for Pulp and Paper Mill Effluents." *Industrial Water and Wastes*. July-August 1963.

Geyer, L. C. "Industry Solves Its Own Sewage and Process Wastes Treatment Problem." *Wastes Engineering*. April 1960.

Gibbs, C. V. and R. H. Boshel. *Potential of Large Metropolitan Sewers for Disposal of Industrial Wastes*. Presented at 31st Meeting of the PNW Pollution Control Assn. Spokane, Washington. October 1964.

Glass, A. C. and K. H. Jenkins. *Statistical Summary of 1962 Inventory of Municipal Waste Facilities in the United States*. U.S.P.H.S. Washington, D. C. 1964.

Gloyna, E. F. and J. F. Malina. "Petrochemical Wastes Effects on Water." *Industrial Water and Wastes*. September-October, November-December 1962, and January-February, March-April 1963.

Graeser, H. J. "Advice to Cities: Get Ready for Industrial Waste Loads." *Industrial Water and Wastes*. May-June 1962.

Gurnham, C. F. (Editor). *Industrial Wastewater Control*. Academic Press. New York, New York. 1965.

________. "Latest Developments in the Treatment of Dairy Wastes." *Industrial Wastes*. July-August 1956.

Hampton, T. R. "Design of Industrial Waste Treatment Facilities at Washington National Airport." *Water and Sewage Works*. October 1966.

Hayes, D. C. "Water Reuse, A Survey of the Pulp and Paper Industry." TAPPI. September 1966.

"Heated Discharges...Their Effect on Streams." Publication No. 3. Pennsylvania Department of Health. January 1962.

Hindin, E. Disposal of Potato Chip Wastes By Anaerobic Digestion. Washington State University Bulletin 255. Pullman, Washington. 1961.

Hopkins, G. J , et al. "Evaluation of Broad Field Disposal of Sugar Beet Wastes." Sewage and Industrial Wastes. December 1956.

Hopkins, G. J. and J. K. Neel. Raw Sewage Lagoons in the Midwest. Purdue Industrial Waste Conference. May 15-17, 1956.

Hoppe, T. C. "Industrial Cooling Water Treatment for Minimum Pollution From Bloudown." Nalco Chemical Co. Reprint. Chicago, Illinois. 1966.

Horton, J. P., et al. "Processing of Phosphorus Furnace Wastes." Sewage and Industrial Wastes. January 1956.

Howe, R. H. L. "Handling Wastes From the Billion Dollar Pharmaceuticals Industry." Wastes Engineering. April 1960.

Hultin, Sven. Calcium Sulphite Spent Liquor Disposal Costs. Helsinki, Finland. February 1963.

Ingols, R. S. "Review of Older Methods for Treating Food Processing Wastes." Industrial Wastes. November-December 1956.

Jaquelt, Z. and N. C. Burbank. "American Cyanamid Simplifies Sludge Handling From Lagoons." Industrial Water and Wastes. July-August 1953.

Kerri, K. D. "A Dynamic Model for Water Quality Control." Journal of the Water Pollution Control Federation. May 1967.

Lamb, J. C. "$4,500,000 Wastes Treatment Plant Dedicated by American Cyanamid Co." Wastes Engineering. August 1958.

Landsberg, H. H., L. L. Fischman, and J. L. Fisher. Resources in America's Future. John Hopkins Press. 1962.

Laugbein, W. B. and W. H. Durum. The Aeration Capacity of Streams. U.S.G.S. Circular 542. Washington, D. C. 1967.

Lardieri, Nicholas Jr. "Industry Has an Important Role in Development of Water Quality Programs." Environmental Science and Technology. May 1967.

Leidner, R. N. "Burns Harbor - Waste Treatment Planning for a New Steel Plant." Journal of the Water Pollution Control Federation. November 1966.

Lindsey, Alan M. "Filters for Dewatering Mixed Primary and Activated Sludge." Presented at 1967 South Central Regional Meeting of the National Council for Stream Improvement. August 1967.

Manufacturing Chemists Association, Inc. "Wastes Treatment and Water Pollution Control Facilities." Survey. 1962.

Manus, L. J. "How to Choose an Industrial Site." Wastes Engineering. June 1957.

________. "Are Our Pollution Parameters Reliable for Chemical Wastes." Wastes Engineering. June 1957.

________. "Should Dairy Wastes Be Converted Into By-Products or Discharged to Sewers?" Wastes Engineering. June 1957.

Mark, R. H. Wastewater Treatment. (A Power Special Report.) New York, New York. June 1967.

Mathur, S. P. Thermal Pollution From Steam-Electric Generating Plants. FWPCA. Cincinnati, Ohio. September 1967.

McBeath, B. C. and R. Eliassen. Optimization of Sewage Treatment Plant Costs. Engineering-Economic Planning Program. Department of Civil Engineering. Stanford University. Stanford, California. July 1965.

McCarty, P. L. "Nutrient-Associated Problems in Water Quality and Treatment-Task Group Report." Journal of the American Water Works Association. October 1966.

McKinney, R. E. "Biological Treatment Systems for Refinery Wastes." Journal of the Water Pollution Control Federation. March 1967.

McLean, J. E. "Disposal of Waste Heat-Thermal Pollution." FWPCA. Memorandum in open file. Washington, D. C.

________. "Notes for Thermal Pollution." FWPCA. Memorandum in open file. Washington, D. C.

________. "Thermal Pollution." FWPCA. Memorandum in open file. Washington, D. C.

Mercer, W. A. "Water Supply and Waste Disposal Problems of the Food Industries." Eleventh Pacific Northwest Industrial Wastes Conference. Oregon State University. Corvallis, Oregon. 1963.

Meyers, N. W. "Waste Disposal in Phosphate Fertilizer Plant Operation." Industrial Water and Wastes. September-October 1963.

________. "Sewage-Wastes Treatment - By Reverse Corporation." Wastes Engineering. June 1957.

Milligan, F. B. "Bethlehem Steel Improves Acid Pickling Wastes Treatment Plant." Wastes Engineering. January 1956.

National Academy of Sciences and National Research Council. Alternatives in Water Management. Publication 1408. Washington, D. C. 1966.

________. Waste Management and Control. Publication 1400. Washington, D. C. 1966.

National Association of Manufacturers and the Chamber of Commerce of the U. S. Water in Industry. New York, New York. January 1965.

National Council for Stream Improvement. Technical Bulletin 120. Appleton, Wisconsin.

Nebolsine, R. and E. J. Donovan. "Fit Wastewater Treatment to Industrial Process." Plant Engineering. June 1966.

Nemerow, N. L. Theories and Practices of Industrial Waste Treatment. Addison-Wesley Publishing Company. Reading, Massachusetts. 1963.

NTA Committee for Water Quality Requirements for Industrial Water Supplies. "Interim Report, June 30, 1967." FWPCA. (In open file.) Washington, D. C.

The Oregonian. "Chemical Plant Prepares Facility for Treatment of 2, 4-D Effluents." Portland, Oregon. February 25, 1966.

Peterson, A. T. Joint Treatment of Municipal and Beet Sugar Waste on High-Rate Trickling Filters. Boise, Idaho. Chronic and Associates, Consulting Engineers. (undated.) (Mimeographed.)

Powers, T. P. "Basic Inter-Relationships of Pollution Abatement Alternatives to Water and Wastewater Quantity and Quality Characteristics." FWPCA. (In open file.) Cincinnati, Ohio. 1967.

Powers, T. P., B. Sachs, and J. Holdaway. "National Industrial Wastewater Assessment, Manufacturing Year, 1963." FWPCA. (In open file.) Cincinnati, Ohio. 1967.

Porges, Ralph. "Waste Loadings From Potato Chip Plants." Sewage and Industrial Wastes. Volume 8, No. 24. August 1952. Pages 1001-1004.

Porges, Ralph and W. W. Towne. "Wastes From the Potato Chip Industry." Sewage and Industrial Wastes. Volume 31. No. 1. January 1959. Pages 53-59.

Quirk, T. P. "How Effective Is Chemical Treatment of Board Mill Process Effluents?" Industrial Water and Wastes. January-February 1963.

Rand, M. C. "Eight Industries and 11 Cities 'Pay the Freight' for Authority Plant." Wastes Engineering. June 1959.

Reid, F. "Two Major Industries Cut Their Wastes Pollution Problems by Self-Analysis." Wastes Engineering. April 1958.

Rose, Walter W. et al. "Composting Fruit Waste Solids." Eleventh Pacific Northwest Industrial Waste Conference. Corvallis State University. (Circular No. 29.) Corvallis, Oregon. 1963. Pages 32-63.

Rowan, P. P., K. L. Jenkins, and D. H. Howells. "Estimating Sewage Treatment Plant Operation and Maintenance Costs." Journal of the Water Pollution Control Federation. February 1961.

Ryckman, D. W., E. D. Edgerley, and N. C. Burbank. "Evaluation and Abatement of Industrial Waste Problems." Industrial Water and Wastes. July-August 1962.

Salbatorelli, J. J. "Aircraft Engine Wastes Treated in Continuous 'Flow-Through' Plant." Wastes Engineering. June 1959.

Saunders, W. F. "How to Recover Investments in Wastes Treatment Plants." Industrial Water and Wastes. March-April 1960.

Schraufnagel, F. H. Waste Disposal By Ridge and Furrow Irrigation. Wisconsin Committee on Water Pollution Report No. WP-108. Madison, Wisconsin. 1963.

Sercu, C. "Burning Industrial Wastes Slurries." Wastes Engineering. January 1959.

Skrotzki, B. C. A. Energy System Economics. (A Power Special Report.) New York, New York. December 1961.

294-046 O - 68 - 12

________. Steam Turbines. (A Power Special Report.) New York, New York. June 1962.

Stanonis, F. L. Subsurface Liquid Waste Disposal in the Canton, Ohio Area. International Disposal Contractors, Inc. Evansville, Indiana.

Steffen, A. J. "The New and the Old in Slaughter House Wastes Treatment Processes." Wastes Engineering. August 1957.

________. "Refiners Make Good Use of Fresh-Water Supplies." Oil and Gas Journal. February 25, 1963.

Stum, Werner, and James J. Morgan. "Stream Pollution By Algal Nutrients." Reprinted from Transactions of the Twelfth Annual Conference on Sanitary Engineering. University of Kansas. 1962.

The Sunday Oregonian. "Beaters Air River Water." Portland, Oregon. July 24, 1966.

Svore, Jerome H. "Sewage Lagoons and Man's Environment." Civil Engineering. Volume 34. No. 9. September 1964.

Sylvester, Robert O. and Goerge C. Anderson. "A Lake's Response to Its Environment." Proceedings of American Society of Civil Engineers, Journal of the Sanitary Engineering Division. Volume 90. No. SA 1. February 1964.

U. S. Atomic Energy Commission. Nuclear Reactors Built, Being Built, or Planned in the United States as of June 30, 1967. Washington, D. C.

U. S. Congress. Federal Water Pollution Control Act, As Amended.

U. S. Department of Commerce, Business and Defense Services Administration. 1967 National Assessment. Part V. Chapter 2. "Industrial Uses."

________. 1963, 1958, and 1954 Census of Manufactures.

________. Projections of Values Added for Specific Industrial Categories, Annually for Years 1969 through 1973 (working tables in open file, FWPCA, Washington, D. C.).

U. S. Department of the Interior. Magnitude of the Thermal Pollution Problem. Internal document of the Interior Committee on Water Resources Research.

U. S. House of Representatives, Committee on Science and Astronautics. The Adequacy of Technology for Pollution Abatement. Government Printing Office. Washington, D. C. 1966.

U. S. Public Health Service. Deep-Well Injection of Liquid Waste. Cincinnati, Ohio. April 1965.

________. Modern Sewage Treatment Plants, How Much Do They Cost? Washington, D. C. 1964.

U. S. Senate, Select Committee on Natural Water Resources, Electric Power in Relation to the Nation's Water Resources. Committee Print No. 10. Water Resources Activities in the United States. Washington, D. C. 1960.

Vacker, D., C. H. Connell, and W. N. Wells. "Phosphate Removal Through Municipal Wastewater Treatment at San Antonio, Texas." Journal of the Water Pollution Control Federation. May 1967.

Voci, J. J. and F. D. Iannuzzi. Factors in Evaluating Sulfite Recovery Systems. A. D. Little and Co. Cambridge, Massachusetts.

Volz, C. J. and J. J. Gannon. "Forecasting Heat Loss in Ponds and Streams." Journal Water Pollution Control Federation. April 1960.

Walden, C. C. Water Use, Reuse and Wastewater Disposal Practices in the Beet Sugar Industry of the United States and Canada. British Columbia Research Council. Vancouver, British Columbia. June 1965.

Walker, K. H. "Each Industry Has Its Own Wastes Problems." Wastes Engineering. July-August-September 1958.

________. "'Package' and Compact Plants - What Makes Them Click?" Wastes Engineering. March 1958.

Watson, C. W. "New Developments in Dairy Waste Treatment." Industrial Water and Wastes. March-April 1961.

________. "Plating Wastes Treatment Problem Solved." Water and Sewage Works. November 1966.

________. "Progress in Air and Stream Pollution Control - Nationwide." Industrial Wastes. July-August 1956.

Wurtz, O. B. and C. E. Renn. Water Temperatures and Aquatic Life, Cooling Water Studies for Edison Electric Institute. The John Hopkins University.

OTHER EFFLUENT REQUIREMENTS
AND COST ESTIMATES

Volume II

Part III

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INTRODUCTION

Conventional waste treatment systems have been designed to accommodate only industrial and municipal wastes. These systems do not deal with such pollutional effects, as those caused by or resulting in sedimentation and erosion, salinity from the use of irrigation water, nutrients from land runoff, mine drainage, concentrated animal feedlot runoff, or radioactive wastes. And there is evidence to indicate that these pollutional sources may eventually become, if they are not now, the principal pollution problems.

Waste Management and Control, a 1966 publication of the National Academy of Sciences and National Research Council, set forth 20 major water polluting agents. Of these, only nine agents were considered susceptible to existing control technology, three (suspended solids, BOD, and bacteria) by application of conventional waste treatment methods, and the others by specific water treatment or materials handling techniques. Significantly, the kinds of pollutants for which there are either no controls, or for which existing controls are uncertain or excessively costly, occur in large part as a result of natural drainage. This absence of control technology makes it impossible to calculate, and hazardous to attempt to estimate, either the timing or the magnitude of necessary control costs.

Despite the long-run difficulties of estimating the costs required to control "other effluents," recognition of their tremendous influence in the water pollution picture reflects the considerable progress made toward overall pollution control in the last several years. Only recently has the full pollutional significance of land drainage begun to be recognized; and problems associated with drainage (heretofore, largely the special concern of the hydrologist) now are being studied and acted upon by sanitary engineers and other water pollution specialists. We are just beginning to understand how large and how prevalent are the pollutional influences of runoff.

Not until evaluation of recent Potomac Basin studies was it generally recognized that land runoff and cattle populations might well be a principal source of coliform bacteria. Similarly, studies during the last decade of the pollutional effects of urban runoff have demonstrated that these effects may be as great or greater than those of sewered municipal wastes. Yet the principal frame of reference for solutions to urban storm water runoff has, until recently, continued to be the separation of storm and sanitary sewers, a measure that will facilitate the efficient operation of the waste treatment plant, but which offers no direct reduction of water pollution from urban runoff.

The polluting effects of land drainage are becoming more pronounced. Runoff is a natural process but many of the conditions which have intensified municipal and industrial waste problems are also magnifying runoff problems. For

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example, concentration of population in urban-suburban complexes, whose large paved areas provide little natural stabilization of organic materials while offering ready channels for their transmission to watercourses, have produced large point deliveries of pollutants. Also, intensive animal husbandry in concentrated areas is replacing broad grazing areas; an arrangement that has facilitated the transfer of large quantities of untreated animal wastes to watercourses. Use of pesticides and herbicides has resulted in totally new and very potent polluting materials which are washed from land into watercourses. Another effect on land drainage is chemical fertilizers. These allow the farmer to synthesize new topsoil cheaply but remove much of the incentive to preserve topsoil, which is allowed to erode, and contributes to turbidity and siltation of waterbodies. And, the abandonment of strip and below-surface mines presents a continuing problem in all types of mine drainage.

While it is impossible to precisely inventory the cost of the many pollution control measures which lie outside the range of municipal and industrial waste treatment, it must be anticipated that such costs will be large. For example, an inventory of pollution control needs, compiled by the Federal Water Pollution Control Administration for interstate drainage basins of the Southwest and Gulf Coast, indicated the costs of controlling "other effluents" would be more than double the estimated costs to meet municipal and industrial waste treatment requirements of these basins.

In summary, then, the discussion which follows should be understood to be merely a start toward defining what may prove to be the most difficult portion of the national water pollution problem. This section delineates major problem areas and, where available, includes a description of remedial procedures and the costs of carrying out these procedures.

In major problem areas for which cost estimates cannot be made because of insufficient knowledge of the problem and its remedies, arrangements have been, or will be, made with other responsible organizations for joint investigation. The results of such studies will be made available to Congress with each yearly updating of this report.

Recognition of the interdisciplinary and interagency aspects of the pollutional problems posed by natural runoff and other effluents required the FWPCA study group assigned to prepare this report, to enlist the assistance of experts from other agencies, both within and without the Department of the Interior. Data and other assistance were supplied by the U. S. Bureau of Mines, the U. S. Geological Survey, the Office of the Secretary of Transportation, the Atomic Energy Commission, and the Federal Power Commission. Particularly broad, informed, and timely assistance was provided by the Department of Agriculture, which produced valuable background papers on animal wastes, salinity, nutrient runoff, erosion, and pesticides through its various offices.

WASTES FROM WATERCRAFT

Watercraft discharges contain several significant polluting agents. Sanitary wastes, including sewage, may carry pathogenic organisms which cause a variety of diseases such as dysentery, typhoid fever, and infectious hepatitis. Concentrations of such wastes make water dangerous for contact sports such as swimming and water-skiing. Oil, bilge, and ballast waters may contaminate waters, destroy aquatic life, and discolor vessels, piers, docks and other structures at the water line. Bilge and ballast waters also may serve to transfer disease-bearing organisms.

A recent report to Congress by the Federal Water Pollution Control Administration[1] provides some estimate of the size of the problem and its remedial cost. The report indicates that in any given year about 110,000 commercial and fishing vessels, about 1,500 Federally-owned vessels, and about 8,000,000 recreational watercraft use the navigable waters of the United States. In addition, about 40,000 foreign ship entrances are recorded each year. The waste discharges from these sources are estimated to be equal to those produced by a city of 500,000 population. However, this estimate probably understates the seriousness of the problem, because watercraft wastes tend to be concentrated in critical areas, such as those used for body-contact water sports, drinking water supplies, shellfish beds, and the like. In addition, as mentioned previously, such waste discharges may present particularly serious health problems.

COSTS

The study emphasized the difficulty involved in estimating the costs of controlling pollution from watercraft. It cited, in particular, lack of treatment and discharge standards and inadequately defined costs of treatment equipment. The installed cost of onboard equipment for properly handling watercraft wastes could vary from $40 to $100,000 per vessel, depending on size, type, mission, and other factors. Based upon the number of vessels of different classes and the wide range of equipment costs, the total cost of bringing all existing American watercraft into compliance with impending regulations will be on the order of $600 million.

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[1] *Wastes From Watercraft*, Federal Water Pollution Control Administration, U. S. Department of the Interior, June 30, 1967.

RADIOACTIVE INDUSTRIAL WASTES

Radioactivity has such serious potentials as an environmental pollutant that only the highest levels of control are acceptable. As a result, the management of radioactive wastes is characterized by an extremely high level of control over very limited quantities of polluting material.

URANIUM MILLING

Nationally the uranium milling industry comprises 16 active mills and two concentrators. These are located as follows: New Mexico, four mills; Wyoming, five mills, one concentrator; Colorado, four mills; Texas, one mill; South Dakota, one mill; and Utah, one mill, one concentrator. The plants process approximately 16,000 tons of ore per day. Historically, activity of the industry rose to a peak, and then decreased according to military requirements. Rapid development of nuclear power generation, however, should provide in the future the uranium milling industry with a stable source of sustained demand.

The process of uranium extraction varies among mills, but includes four basic steps common to all mills: crushing, grinding, leaching, and uranium recovery. It is the leaching process which produces liquid wastes, with the chemical composition of the ores determining whether an acid or an alkali leach is appropriate.

Thirteen of the 16 active mills utilize an acid leach. This process generates large quantities of wastewater; 500 to 1,200 gallons per ton of ore processed. Uranium is recovered in the acid leach process by multi-stage extraction processes, usually ion exchange and/or solvent extraction followed by chemical precipitation. Alkaline leaching produces a uranium-bearing liquor with few dissolved impurities. This allows uranium recovering by direct chemical precipitation, without the need for concentration by ion exchange or solvent extraction. The barren liquor (raffinate) of alkaline leaching is recycled, and wastewater discharge averages 250 gallons per ton of ore processed, less than a third of the wastewater quantities associated with the acid leaching process.

Essentially all of the radium dissolved by alkaline leaching is precipitated together with uranium, thereby leaving the plant in the uranium concentrate product. In acid leaching, however, dissolved radium is discharged in the waste stream, averaging about three micrograms of dissolved radium per ton of ore processed. In either leaching process, the uranium mills discharge significant quantities of inorganic, non-radioactive waste materials. Total dissolved solids range between 4,500 and 20,000 milligrams per liter in the wastewater, which tends to be either strongly acid or highly alkaline, depending upon the process used.

The industry's standardized waste control practice involves the use of holding ponds for the retention and concentration of the liquid and solid wastes. These ponds serve as reservoirs for water reuse, provide removal of waste solids by sedimentation, and allow the evaporation and seepage of the liquid wastes. During periods of high runoff, the liquid wastes may be released to surface waters in accordance with available dilution, but evaporation and seepage are the principal means of dispersal. Standards for design and operation of holding ponds are stringent, stressing materials' stability against erosion from runoff, precipitation, and wind action as well as control of liquid releases. Seepage, however, is a problem in some areas. Inspection of uranium mill sites in the Colorado River Basin has revealed some adverse effects on adjacent ground waters. Potential pollution from this source is a subject for further study. An additional problem is posed by the existence of unstabilized piles of tailings at inactive or abandoned mills. Placement of responsibility for control, and procedure therefore, have posed problems, but have been adjusted by cooperative State-Federal-Industry agreements.

NUCLEAR POWER

The increased generation of electrical energy through the use of nuclear power will require continuing and close control over the release of radioactive effluents. Nuclear generating capacity at the close of 1967 exceeded 2,800 megawatts; by 1973, the scheduled total of 72 reactors will be generating almost 46,000 megawatts.

With the exception of the heat source, electrical generation in nuclear plants is very similar to the process in conventional thermal generating plants. Where conventional plants derive their thermal energy from combustion of fossil fuels, nuclear plants utilize the controlled nuclear fission of uranium as an energy source. One waste product, heat, is similar in the two types. But where conventional plants release smoke, ash, and gases to the atmosphere, nuclear plants release small quantities of radioactive isotopes to the environment.

Radioactive material is produced by two processes which occur within the energy source, the reactor. The fission process itself forms a variety of isotopes, which remain for the most part within the matrix of the fuel material. A high integrity material which encloses the fuel material serves to prevent the fission fragments which escape the matrix from entering the cooling system surrounding the reactor. Nevertheless, some quanitites of fission products enter the coolant as a result of defects in the covering material, by diffusion through the covering, or by contamination on the outer surface of the covering.

Neutron activation is the other possible source of radiological contamination in a reactor system. Radioactivity is produced by exposing stable nuclides to neutron bombardment. It is a characteristic of reactor operation that neutron activation will occur, and that activated products will go into solution or suspension in the coolant as corrosion takes place. Removal of the radionuclides from the coolant is necessary to prevent excessive accumulation of radioactivity. This is accomplished by cycling a portion of the coolant through a clean-up process, usually filtration followed by ion exchange.

Liquid radioactive wastes arise from several sources in the generating plant. These sources include leakage of the primary coolant, effluent of the coolant clean-up system, the fuel storage pool, laboratory operations, and laundry drains. Such wastes are treated by batch process in specific radioactive waste treatment systems, usually by filtration, followed by demineralization and/or evaporation. Treated wastes are collected and analyzed. Depending upon the analysis and system requirements for the primary coolant, the treated wastes are reprocessed and either returned to the cooling system or discharged with cooling water effluents.

Criteria for routine radioactive effluent discharges have been established by the Atomic Energy Commission based on the recommendations of the Federal Radiation Council (FRC), National Council on Radiation Protection and Measurements (NCRPM), and the International Commission on Radiological Protection (ICRP). As a general rule, liquid effluent radioactivity concentrations are several orders of magnitude below levels which would result in exposures exceeding FRC guides. In no case are operations allowed which would result in radiation exposures exceeding the guides established by the Federal Radiation Council.

TREATMENT COSTS

Treatment costs involve projecting the level of production over the next several years and assigning appropriate unit costs. It is necessary to assume arbitrarily static processing and treatment technology because it is difficult, in such a rapidly developing industry, to forecast the direction and extent of future unit cost modifications.

Uranium milling treatment costs vary from mill to mill, depending upon the leaching process, the location of disposal areas, and neutralization requirements. It should be noted that it is impossible to separate, realistically, the costs of solid and liquid waste disposal since the tailings pile which serves as the dump for solid wastes may serve also as the settling pond for liquid wastes.

For uranium milling, an average cost of 80 cents per ton of ore processed has been estimated for waste treatment measures.[2] This assumes that the industry's current productive capacity is sufficient to meet the uranium demand over the projected period and that the average quality of ores processed remains constant. On this basis, an annual cost of about $3.2 million will be required. Of this cost, about $0.6 million represents capital requirements, and the remainder comprises operating and maintenance costs.

Another factor in treatment costs is control measures at inactive mills. The control of mill tailings piles will constitute a significant portion of the treatment cost for radioactive pollution control. Control cost estimates obtained for inactive mills in the Colorado River Basin have ranged from $300,000 to $500,000 per establishment, depending upon the type of control.

Because of limited current experience, there is no extensive body of cost data related to the control of radioactive discharges of nuclear generating plants. There is, however, enough experience with plants which have been in operation for a period of years to provide approximate guides to operating and construction costs associated with building and maintaining nuclear waste treatment plants. The experience is that installation of treatment facilities for nuclear wastes amounts to about 1% to 2% of the total cost of a nuclear plant, and operation and maintenance of the system accounts for about 0.3% of total generating costs.

Application of these treatment cost factors to existing and planned nuclear plants, with plant costs evaluated at $1.31 per kilowatt of capacity and generating costs of 3.024 mills per kilowatt[3], provides the gross assessment of treatment costs associated with construction and operation of nuclear generating facilities as presented in Table III-1. On this basis, capital costs for nuclear waste treatment facilities are expected to lie within a range of $60 million to $120 million over the five-year period ending with 1973.

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[2] *Lammering, M. W., Federal Water Pollution Control Administration in-house file, August 4, 1967.*

[3] *Average unit cost for four 100 megawatt plants proposed for construction in the period 1967-1970.*

TABLE III-1

TREATMENT COSTS FOR RADIOACTIVE WASTES, 1957-1973

Startup Date	Reactors Starting Operation	Megawatts of Generating Capacity on Stream in Year	Capital Value of Associated Treatment Facilities ($ Millions) (Range)	Annual Operating Costs in Year ($ Millions)
1957-1967	16[1]	2,810	3.68 - 7.36	.67
1968	2	1,015	1.33 - 2.66	1.12
1969	5	3,272	4.29 - 8.58	1.85
1970	7	4,241	5.56 - 11.12	3.87
1971	15	12,455	16.31 - 32.62	7.97
1972	14	10,853	14.22 - 28.44	11.89
1973	13	11,186	14.65 - 29.30	16.27
TOTAL	72	45,832	60.04 - 120.08	

[1] *Excludes Hallam and Carolinas-Virginia Test Reactors which have been shut down.*

Source: Atomic Energy Commission

EROSION AND SEDIMENTATION

Sediments produced by erosion of the land surface are the most extensive pollutants of surface waters. Suspended solids loadings reaching the Nation's streams from surface runoff are estimated to be at least 700 times the loading from domestic sewage discharge. The same estimate places the quantity of sediment carried by streamflow and discharged to the oceans each year at something approaching one billion tons. The quantity of sediment reaching the oceans, however, is only a fraction of the total amount effected by erosion. On an average, it is probable that at least four billion tons of soil are moved each year by water. This is roughly equivalent to removing one-half inch of surface solids from about 50 million acres of land each year.

DAMAGING EFFECTS

The damaging effects of sedimentation are varied. Nutrients, particularly phosphorus adsorbed on sediment particles, may be a source of enrichment and consequent eutrophication[4] of lakes and other surface waters. The oxidation of organic pollutants is hindered by sediments in streams. Both commercial fisheries and game fish habitats are damaged by waterborne and deposited sediment. Corrosion of power turbines, pumping equipment, irrigation distribution systems and other structures is caused by impact with suspended sediment.

Flood-borne sediment deposited on productive flood plains may damage crops and, if sufficiently coarse-textured, may reduce the productivity of the soils. Sediment deposits in stream channels reduce the stream's capacity to convey water and sometimes seriously impair the drainage of adjacent lands. Suspended sediment in water used for artificial recharge of underground aquifers presents problems by clogging the aquifer pore spaces, and costs are incurred in clearing the water before it can be used.

Storage capacity of artificial reservoirs is being depleted at the rate of about one million acre-feet each year by deposition of sediment. (Capacity for all artificial reservoirs in the U. S. was estimated to be about 1.8 billion acre-feet in 1966.)[5] This damage is reflected in the loss of storage capacity for water supply, flood control, power generation, navigation, and streamflow regulation for water quality control.

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[4] *Eutrophication is the excessive fertilization of algae and other aquatic plants with nutrients, principally phosphates - a common element found in municipal sewage, human waste, agricultural fertilizers and industrial discharges, and nitrates.*

[5] *Water Resources Research, Volume II, No. 3, R.F.F., 3rd quarter, 1966, pp. 323-354.*

Pollution also affects recreational areas. The deposition of sediment on beaches reduces their utility for swimming, fishing or boating, and detracts from their aesthetic quality. There are instances where formerly clear reservoirs have experienced significant reductions in both visitor days and fish catch because of excessive turbidity of the lake water due to sediment inflow.

The impact of stream-borne sediment upon the economy as well as the quality of our environment is of tremendous significance. A rough estimate is that sediment damage costs are well in excess of $500 million annually. Moreover, the loss of soil resources by erosion is very likely several times greater than the combined direct and indirect sediment damage costs.

The physical magnitude of the sediment problem is indicated in Table III-2. Ranges are shown of average sediment yield in tons per square mile per year from areas of 100 square miles or less. The figures are based largely on an analysis of sedimentation surveys of reservoirs in Water Resource Regions with drainage areas of 100 square miles or less. Particularly striking are the differences in average sediment yield among regions (from 50 to 5,200 tons per square mile per year).

SOURCES OF SEDIMENT

Erosion is the major cause of sedimentation. Although erosion is recognized as a normal geological process, its normal effect has been accelerated by agricultural and forestry activities, construction of roads and highways, and industrial and urban development. This accelerated erosion has increased the production of sediment far above that experienced when the country was first settled. It has been estimated, for example, that man-induced erosion has increased the sediment load of streams in the humid areas of the United States by a factor ranging from 25 to 100; and that most streams in the arid and semi-arid areas carry two to four times their original sediment load. It is largely this induced erosion that is susceptible to control.

The principal sources of sediment are: (1) sheet erosion by surface runoff which does not cause conspicuous water channels; (2) gullying, or the development of channels in soil by concentrated runoff; (3) roadside erosion or the washing away of material from cuts, fills and surfaces of transportation lines; (4) stream channel erosion; (5) flood erosion or the scouring of flood-plain lands by floodflows; (6) erosion from construction activities such as those involved in urbanization and industrial development; and (7) mining and industrial wastes dumped into streams or left in positions susceptible to erosion.

Many examples of the importance of the several sources of sediment and how they vary in different portions of the country can be cited. Sources of the sediment yield presently experienced in the Middle Fork Eel River in the Cal-

TABLE III-2

ESTIMATED RANGES IN SEDIMENT YIELD FROM DRAINAGE AREAS OF 100 SQUARE MILES OR LESS, BY WATER RESOURCE REGION

Water Resource Region	Estimated Sediment Yield		
	High	Low	Average
	(Tons/sq. mi./yr.)		
North Atlantic	1,210	30	250
South Atlantic	1,850	100	800
Ohio	2,110	160	850
Tennessee	1,560	460	700
Great Lakes	800	10	100
Upper Mississippi	3,900	10	800
Lower Mississippi	8,210	1,560	5,200
Texas-Gulf	3,180	90	1,800
Rio Grande	3,340	150	1,300
Arkansas-White-Red	8,210	260	2,200
Missouri	6,700	10	1,500
Souris-Red-Rainy	470	10	50
Upper Colorado	3,340	150	1,800
Lower Colorado	1,620	150	600
Great Basin	1,780	100	400
California	5,570	80	1,300
Columbia - North Pacific	1,100	30	400

Source: Agricultural Research Service, U.S.D.A.; Miscellaneous Publication, No. 964, 1964.

ifornia Water Resource Region are: (1) watershed slopes - 13.5%, (2) landslides - 22.5%, (3) stream banks - 63.0%, (4) major roads - 1.0%. Interestingly, the 13.5% arising from watershed slopes breaks down as follows: (1) natural causes - 42.7%, (2) logging - 7.7%, (3) burns - 3.2%, (4) grazing - 24.6%, (5) deer - 19.5% (as the result of browsing and hindrance to reproduction of vegetation), and (6) temporary logging roads - 2.3%.

The Potomac River Basin in the North Atlantic Water Resource Region discharges an estimated 2,500,000 tons of sediment to the Potomac estuary each year. While agricultural lands of the basin produce the major portion of the sediment, construction activities produce a disproportionately large share when relative area is considered.

While the sources of sediment are similar in all parts of the country, the preceding examples indicate that the relative importance of each source varies widely. Each area of the country must be considered separately to determine the importance of each source in order to carry out effective controls. The following control methods are expressed mainly in terms of land use, but consideration must be given to climatic factors, soils, geology, topography and stream channel characteristics in recommending methods of control.

METHODS OF CONTROL

Proper use of land is basic to the control of sediment originating in upland areas. Sheet erosion on farmlands can be reduced by the application of many available conservation measures. Such measures include conservation rotations, the establishment and improvement of long-term ground cover of hay and pasture grasses or legumes, mulching, and critical area plantings. In connection with such agronomic practices, complementary field mechanical measures such as stripcropping, terracing, and diversions are often recommended. In combination, these and supporting mechanical field measures can reduce substantially the movement of soil materials by erosion. Forestry measures include site preparation, the planting of trees on burned, cut-over or abandoned farmlands, as well as the interplanting of existing woodlands.

Channel-type erosion, such as gullying and streambank and stream-bed erosion, usually requires more elaborate structural measures. Grade stabilization structures, sloping and vegetating stream banks and gullies, and construction of debris basins and sediment detention basins are among the structural works employed to reduce sediment yields from these channel-type sources.

Urban erosion and sedimentation stem principally from road building and construction projects. Measures such as prompt reseeding of exposed areas, use of mulches, temporary settling basins, or diversion can effect significant reductions in sediment yield from urban erosion sources.

EFFECTS OF CONTROL

There is considerable evidence that sediment can be reduced by the measures discussed above. Agronomic and supporting mechanical field practices have reduced the amount of sediment that reaches reservoirs by amounts ranging from 28% to 73%. Good conservation practices on cultivated watersheds have reduced sediment yields by almost 90%. The protection of existing forest and range lands indicates such measures may reduce sediment yields by 90%. Streambank protection work on Buffalo Creek, New York, reduced sediment delivery to Buffalo Harbor during flood flows by 40%.

ACID MINE DRAINAGE

Acid mine drainage is not the only pollutant being discharged by active and abandoned mining operations. Other constituents found in mine drainage, such as iron, sulfate, manganese, etc., sometimes have a more detrimental effect on the quality of the receiving waters than the acid loadings. However, the mine drainage problem has been considered largely in terms of acid production, which is the major source of water pollution by mining. As information becomes available, analyses of currently less critical mine drainage problems may be included in future reports.

Current estimates are that over four million tons of acid-equivalents are discharged annually into streams by active or abandoned mining operations.[6] When the cumulative quantity discharged becomes great enough to exceed the natural neutralizing capacity of the waterbody, damages occur to fish and fish food organisms, recreational and aesthetic values, and structures and equipment exposed to the water. Costs for pretreatment of water intended for municipal or industrial supplies are also increased. It is estimated that over 4,300 miles of stream in the U. S. are polluted significantly by acid mine drainage.

Acid mine water is associated predominantly with working of coal deposits. Accordingly, its pollutional effects are most evident in the coal mining states - West Virginia, Pennsylvania, Illinois, Kentucky, and Ohio. Acid drainage also has been pinpointed as the largest pollution problem of the heavily industrialized Ohio River Basin. But acid waters have been found to occur from mining of other kinds of ores; and isolated instances of water pollution caused by acid mine waters are found elsewhere throughout the Nation.

In addition to the acid problem, mining tends to be accompanied by excessive siltation. Sediment yields from strip-mined areas average nearly 30,000 tons per square mile annually - 10 to 60 times the yields of otherwise-worked lands. Spoilbank surfaces from stripped areas are often too acid to re-establish the vegetation which would halt the excessive erosion. The reaction of minerals in the eroded soils with receiving waters is a source of acid release. Thus, strip-mining, the source of an estimated one-quarter of polluting acid mine waters, is at the same time a major source of erosion.

Somewhat more than half of the acid production comes from abandoned mines, both surface and underground, and the remainder from operating mines. The three classes of mining - strip, underground above drainage, and underground below drainage - require different control measures. Measures that are effective in reducing acid production from abandoned mines cannot be applied to operating mines where, in many cases, actual treatment of the mine effluent must be initiated.

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[6] *Bullard, W. E., "National Program for Prevention and Control of Pollution From Mine Drainage," in-house report, Department of the Interior, FWPCA, April 14, 1967, p. 4.*

In examining the magnitude of the problem, "A Study of Surface Mining and Our Environment" found that 3.2 million acres of land have been affected by surface mining. More than two-thirds of this total acreage is unreclaimed. Large amounts of this acreage will require corrective action to alleviate detrimental effects or to restore the land to some type of productive use. The extension of areas disturbed by acid drainage is continuing at an estimated 150,000 acres per year, with the rate increasing as a larger population and a larger per-capita output of goods create a greater demand for materials.

By means of enforced regulations and effective sanctions, operating mines can utilize existing methods to control their pollutional effects in the regular course of operations. Remedial solutions to mine pollution are costly but they minimize damages by lessening the degree of environmental exposure.

Continuous reclamation can be conducted in strip-mining operations by stockpiling topsoil, then burying acid-producing materials at the bottom of the strip pit, and covering it with the stockpiled topsoil. Reclamation of underground mines can be accomplished by collecting infiltrating waters, providing lined drains and construction of internal seals. Flooding of abandoned mine sections to reduce acid production at the source, and treating or neutralizing the discharges before releasing them to streams or ground water are also effective methods in controlling mine wastes. Several states require that mining be limited to areas where harmful effects can be ameliorated. Many states require post-operative reclamation or control of pollution damages. But a general policy of reduction of environmental damages from mining remains to be established.

Abandoned mining operations present an entirely different abatement problem. In such cases past generations of producers have ignored reclamation costs, which were generally accepted to be a public responsibility. That responsibility extends to about two million acres of abandoned mined lands, plus a smaller, but significant, subsurface drainage problem. Abandoned pollution-producing strip-mined lands must be reclaimed; pollution-producing surface waste piles derived from underground mines must be controlled; subsidence holes and drainage discharges must be sealed; and, in some cases, water treatment will be needed to limit residual pollution after physical control of acid-producing sites has been inaugurated.

Control procedures for strip-mines are governed by the condition of the abandoned site. Major features may include steep, crumbling, hazardous highwalls that sometimes isolate ridgetops, pits that are often full of red acid water, and long parallel ridges of rock and soil that overburden from above the mine deposit. An estimated 20% of coal strip-mining spoilbanks contribute to acid pollution of streams receiving their drainage. Nearly all of them at some time contribute large volumes of sediment. Because of the high acid content, steep slopes with shifting surface layers, and the often shaly and drouthy nature of the surface, these spoilbanks present sites hostile to the growth of vegetation. Standard reclamation practice calls for rounding spoilbank ridges, grading spoils to natural contours, or to traversable grades, burying toxic spoilbank material, backfilling spoil against the highwall to cover exposed pollution-producing mineral formations, rounding hazardous highwall crests, and revegetating for stabilization of the spoil. Strip pits may be left open and allowed to fill with water to provide recreation areas. Long slopes may be terraced to aid erosion control, and drainage diversions and channels may be installed for that purpose, and to keep water from leaching pollutants from spoil. The final step of revegetation may include both a quick cover crop of grasses and legumes for soil stabilization and tree planting. Where high acidity in the surface prevents establishment of plants, contour furrowing may promote leaching and prepare the site for the existence of the hardier, adaptable species. The addition of lime and fertilizer has been shown to increase the success and encourage the rapid growth of vegetation. These methods have been established, applied, and found effective.

Several methods may be sufficient to deal with problems presented by underground mines below drainage. As a mine fills with water, oxidation processes and acid production diminish and stop. But, where there is through-flow across the body of water trapped in the mine, or where there is seasonal fluctuation in the water level, there may continue to be enough acid production to cause significant pollution. Various methods of coping with this situation have been suggested - backfilling mine galleries, injecting neutralizing agents that produce a sludge to blanket the acid-producing materials, injecting chemicals to immobilize and prevent oxidation of sulfur minerals, and sealing the surface to prevent or reduce percolation to the mines, as well to treat the effluent. The adequacy of these methods remains to be proved.

The most difficult problem is presented by underground mines above drainage. Some methods have been applied successfully in several situations, notably air-sealing and drainage diversion. The success of these methods appears to be related to the proportion of openings which are closed and which would otherwise permit entry of air and water to the mines. Numerous other methods have been proposed that appear worth testing. They include injecting reactive gases into mine galleries to immobilize and prevent oxidation of sulfur minerals, grouting to make fractured layers above mineral seams impermeable, and grouting with chemical solutions to bind sulfur.

To summarize physical solutions to the acid mine drainage pollution problem, there are available established prevention and control methods to apply to most strip-mined areas, to most of the underground mines below drainage, and to the less complex situations in the underground mines above drainage. We are on the track of economic methods for treating significant drainage residuals from abandoned mines as well as effluents from operating mines. In the future, modified mining methods in stripping operations can be utilized for reducing acid pollution.

COSTS

The FWPCA Acid Mine Drainage Pollution Control Demonstration Program has developed some standardized cost relationships which provide an insight into the general magnitude of the cost requirements associated with controlling acid mine drainage. It should be stressed that the costs, as presented here, refer only to reclamation of abandoned sites. In the absence of adequate controls over mining procedures, such costs would have to be projected into the future on the assumption that remedies will continue to be borne by the public. If adequate controls are enforced, future costs will be reflected in total production costs and either borne by producers or passed on by them to consumers. In either case, there are no existing estimates of the dimensions of such costs.

This assessment is presented in terms of a minimum and a recommended solution to the problem. The minimum solution is considered to be one which would accomplish significant reductions in pollution from acid drainage without regard to accompanying requirements for restoration of land use capabilities or other potential benefits, and with only a minimum of research necessary to develop effective treatments for cleaning up effluents from active mines and major pollution residuals. For strip-mined areas it would include basic reclamation of 1.12 million acres at a cost of $360 per acre or a total of $400 million. Sealing underground mines would cost $225 million. Purchase of land would cost an estimated $40 million. Program operations would cost over $2.5 million a year for 20 years. This minimum program would thus cost about $700 million, assuming no further pollution from current and future mining operations. It is estimated that this minimum program would result in reductions of from two-fifths to three-fifths of existing acid mine drainage pollution. It would have the additional benefit of considerably reducing sediment pollution from mine spoilbanks and wastepiles.

A more extensive solution to the acid mine drainage problem would increase expenditures. It would involve work on approximately 2.2 million acres of strip-mined land, to put the land back into uses planned and integrated with the uses of surrounding lands and the needs of nearby metropolitan centers. At an estimated average cost of $920 per acre, the cost would total $2 billion. For this more substantial operation, purchase of a greater percentage of the land would be necessary - an estimated total cost of $85 million. Sealing underground mines and treating subsidence areas would add an estimated $900 million. Program operation would cost an estimated $4 million a year for 20 years, or $80 million. A grand total for the program is, then, $3.1 billion. (Table III-3.)

TABLE III-3

ESTIMATED COST RANGE TO REDUCE ACID MINE DRAINAGE BY 40% TO 80% OVER NEXT 20 YEARS

Cost Element	Range in Cost ($ Millions)		
Reclaiming Abandoned Stripmine Areas	400	-	2,000
Land Purchase	40	-	85
Sealing Underground Mines	225	-	900
Operation for 20 Years (Not Discounted)	50	-	80
TOTAL	715	-	3,065

Source: In-House Document, Federal Water Pollution Control Administration, U. S. Department of the Interior, April 14, 1967. (Does not include costs of construction of treatment plants and research and development programs.)

This solution would bring about a reduction of at least four-fifths of the pollution presently attributed to acid mine drainage. It would provide considerable further benefits in almost complete reduction of sediment pollution from mining activities. Enhancement of land values and land uses would extend well beyond the boundaries of the treated acres. (Table III-4.)

TABLE III-4

RANGE OF POLLUTION CONTROL COSTS IN MINE DRAINAGE MANAGEMENT

Item	Range or Average Cost (Dollars)
Sealing Underground Mines	1,000 - 2,000
Grouting - No data available	
Surface Mine Reclamation -	
Earth Moving - cubic yard	.05 - .10
Surface Grading - per acre	71 - 350
Planting Costs: Trees - per acre	35
Trees, ground cover, fertilizing, per acre	125
Costs of complete reclamation including grading and planting, per acre	106 - 475
Drainage Diversion, per foot	6
Impoundments per acre-foot	500
Refuse and Gob	
Hauling - per ton mile	.10
Reclamation at site per acre	600
Control and Treatment (mil. gal. per ft. of pumping)	.08 - .09
Treatment (neutralization - per thous. gal.)	.03 - 1.29

Source: *Handbook of Pollution Control Costs in Mine Drainage Management, U. S. Department of the Interior, FWPCA, December 1966.*

FEEDLOT POLLUTION

Animal wastes include liquids and solid wastes that are either excreted by animals - farm livestock, wild animals, and pets - or arise from practices associated with their care and utilization. This report is concerned primarily with the livestock production aspects of animals used for food and fiber. Not only the excreta but the by-products of feeding and sanitation are involved.

Animal wastes may contribute to water pollution in many ways. Involved are: (1) excessive nutrients that unbalance natural ecological systems causing excessive aquatic plant growth and fish kills; (2) microorganisms that are pathogenic to animals, including man; (3) dissolved toxic impurities in drinking water; (4) solids that load water filtration systems and complicate water treatment; (5) taste and odor in water; and (6) consumption of dissolved oxygen, producing stress on aquatic populations and occasionally producing septic conditions.

Animal wastes have been also associated with malodorous emissions from lakes, rivers, streams, and other waterbodies. Methods of entry vary. Surface drainage from cattle feedlots and other areas where animals are concentrated in relatively large groups, has created considerable national concern. However, other problems such as seepage downward into aquifers, direct deposition of excreta by domestic and wild animals either at the edge of or in waterbodies, runoff from city streets, drains from animal quarters and milking rooms, seepage from silos, runoff from manured fields, and effluents from animal waste disposal lagoons are also significant.

Animal wastes may be the prime pollution contributor in some areas of the country; for example, certain sections of the Midwest have feedlots on small watersheds where animal concentrations are extremely high. Heavy storms flush slug loadings of animal wastes into a small stream; the volume of stormwater, however, is insufficient to provide adequate dilution along the entire watercourse. Fish kills and lowered recreational values often result.

MAGNITUDE OF THE PROBLEM

Nearly all grain-fed cattle spend the last three to five months of their 1-1/2 to two years of life in feedlot confinement. Although feedlot drainage can be as detrimental to a body of water as can untreated industrial and municipal wastes, very little planning has been done to curb the pollutional effect of feedlots.

Cattle feedlots are the major producer of concentrated animal wastes. However, there are other important sources of animal-related pollution which are

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detrimental to health and the environment. These sources include multi-hundred cow dairy operations, hog feedlots where many thousands of animals are fed annually, and chicken and turkey operations feeding 100,000 or more birds annually. Disposal of such wastes has become a problem, and economic studies indicate that the cost of handling manures is higher than the costs of handling equivalent quantities of chemical fertilizers.

Table III-5 indicates the amount of solid wastes produced by livestock in the United States. In addition to the wastes generated by commercial livestock, as shown in this table, domestic animals produce over a billion tons of fecal wastes a year. Liquid effluent amounts to over 400 million tons. Used bedding, paunch manure from slaughterhouses, and dead carcasses raise the total annual production of animal wastes to almost two billion tons. Possibly half of this waste is produced under concentrated conditions. It also should be noted that cattle in a feedlot for fattening, or dairy cows maintained for high milk production, may produce double the daily amount of wastes shown in the table.

It is of interest also to consider Table III-6 showing the population equivalent of the fecal production by various kinds of livestock in terms of standard BOD. For example, a feedlot carrying 10,000 cattle has about the same sewage disposal population equivalent problem of a city of 165,000 people. The city will be using 8.2 million gallons of water a day to carry off its sewage. Such amounts of water are never used and are seldom even available at the feedlot.

Wastes carried in runoff from barnyards and feedlots may vary in BOD content from 100 to 10,000 parts per million (ppm) depending on dilution and degree of deterioration of wastes. Pollution control authorities object to runoff entering a stream if it exceeds 20 ppm of BOD. Hence, the problem is a serious one in many areas.

Treatment systems using lagoons for the oxidation of animal wastes have been tried on many feedlots. Success has not been complete. These lagoons are plagued by problems such as overloading, floating litter, intermittent loading, aquatic weeds, and sludge buildup. When a lagoon becomes overloaded, bacteriological decomposition changes from that caused by oxygen using bacteria (aerobic) to that caused by bacteria which operate in the absence of oxygen (anaerobic). During anaerobic decomposition, noxious gases and odors are produced. Under such conditions, the lagoon becomes even more malodorous than the ordinary manure pile.

To date, evaluations of river basin and watershed sources of pollution do not provide a complete national picture of the role of animal wastes in water pollution. The Potomac River Basin (more than 14,000 square miles) has been adopted for use as a model for evaluation, and analysis of this basin will provide some insight into the role of animal wastes. The evaluation of the bacteriological aspects of pollution (coliforms, fecal coliforms, and fecal

TABLE III-5

SOLID WASTES PRODUCED BY LIVESTOCK IN THE UNITED STATES, 1965

Livestock	U. S. Population, 1965 (millions)	Solid Wastes[1] (gms./cap./day)	Total Production Solid Wastes tons/year (millions)	Liquid Wastes (gms./cap./day)	Total Production Liquid Wastes tons/year (millions)
Cattle	107	23,600	1,004.0	9,000	390.4
Horses[2]	3	16,100	17.5	3,600	4.4
Hogs	53	2,700	57.3	1,600	33.9
Sheep	26	1,130	11.8	680	7.1
Chickens	375	182	27.4	-	-
Turkeys	104	448	19.0	-	-
Ducks	11	336	1.6	-	-
TOTAL			1,138.6		435.8

[1] *Jour. Water Pollution Control Federation 34:295*

[2] *Horses and miles on farms as work stock*

Source: *Wastes in Relation to Agriculture, Unpublished manuscript, U. S. Department of Agriculture, April 1967.*

TABLE III-6

FECAL DISCHARGE FROM SPECIFIED ANIMAL TYPES

Animal	Fecal Discharge (gms./cap./day)	Relative Discharge Compared to Man's Waste (units)	Relative BOD Per Unit of Waste (units)	Population Equivalent
Man	150	1.0	1.000	1.00
Horse	16,100	107.0	0.105	11.30
Cow	23,600	157.0	0.105	16.40
Sheep	1,130	7.0	0.325	2.45
Hog	2,700	18.0	0.105	1.90
Hen	182	1.2	0.115	0.14

Source: *Wastes in Relation to Agriculture*, *C. H. Wadleigh, Unpublished Manuscript, U. S. Department of Agriculture, April 1967.*

streptococci) revealed that animal wastes are a major source of pollution. The ratio of fecal coliforms to fecal streptococci was used as an index of animal/human waste contribution. Several sampling points consistently yielded a ratio of less than one, an accepted indication that bacterial contamination was non-human in origin. Table III-7 provides a comparative example of animal waste equivalence to untreated human wastes by sub-basins within the Potomac Basin. This table takes into consideration the greater population equivalent of animal wastes as compared to human sewage.

TABLE III-7

ANIMAL WASTE EQUIVALENCE TO UNTREATED HUMAN WASTE BY SUB-BASINS OF THE POTOMAC RIVER

Potomac River above Shepherdstown, W. Va.	800,000 people
Shenandoah River above Charles Town, W. Va.	1,400,000 people
Monocacy River above Frederick, Md.	700,000 people
TOTAL	2,900,000 people

The total human waste equivalence of the animal wastes is nearly six times the human population (approximately 500,000 people) and more than 10 times the sewered population (275,000 people) in the area.

Up to the time of the Potomac study, animal wastes were considered a pollution source only in small streams or lakes. The Potomac study has demonstrated the pollution potential of animal wastes in all river basins. The upper limits of the animal waste problem on a national scale may be illustrated by estimates that, in terms of standard BOD, U. S. farm animal waste production is 10 times greater than U. S. human sewage.

Although the Potomac Basin studies provide the only currently available quantitative documentation of the role of animal wastes in water pollution relative to other wastes, there exists substantial evidence of the potential for farm animal wastes to pollute water. The presence of the infectious agents in water are always a concern, particularly in beach areas, surface waters consumed directly by animals, and underground water supplies used by rural dwellers. Infectious agents from animals which may pollute streams are anthrax, brucellosis, coccidiosis, encephalitis, erysipelas, foot rot, histoplasmosis, hog cholera, infectious bronchitis, nastitis, Newcastle disease, ornithosis, transmissible gastroenteritis, salmonellosis, and leptospirosis. Outbreaks of infections from these agents have been reported in numerous instances.

Looking at the national profile of the potential of farm animal wastes as a source of excessive nutrients to streams, total nitrogen would average about 10 million tons, phosphorus about 2.5 million tons, and potassium about 7.5 million tons. These are substantial quantities of nutrients, but in terms of total nutrients uniformly distributed in all waterbodies, their significance is greatly diminished.

PROCESSES CAUSING POLLUTION FROM FEEDLOTS

To meet the ever-increasing demand for high quality beef, the feedlot has been utilized as a means of producing a high grade carcass in a relatively short time. Cattle received in feedlots usually range in weight from 400 to 800 pounds per head. During the time cattle are in the feedlot, each animal is expected to gain about 2-1/2 pounds per day. Therefore, over the 120 to 150-day feeding period, the animals leave the feedlot weighing from 750 to 1,200 pounds each. Indications are that the feeding period and the weight of animals leaving the feedlot are increasing. A feedlot with a capacity of 5,000 head covers approximately 35 acres, an average of about 300 square feet per animal. Each day cattle consume about 3% of their body weight in total feeds. About two-thirds of this quantity is grain and protein. The other one-third is roughage. A 1,000-pound animal consumes about 20 pounds of grain and protein and about 10 pounds of roughage per day. Animals confined in feedlots normally consume between 10 and 20 gallons of water daily. Animals so fed produce an average of about 64 pounds of wet manure per day; and the nutritionally balanced feed results in a body waste having greater water pollution potential than is found with grassland grazed cattle.

Cattle feedlots are seldom cleaned more than two to three times per year; usually manure is removed only once per year. Periodically, however, manure on the floor of each feeding pen is mounded in a central location in the pen. This mounding allows the animals a clean area in which to stand. Occasionally, cattle feedlots have a concrete surface pen, where experimental work has shown animals gain one-third pound per head more daily than those in muddy pens. To minimize the mud problem, lots are normally constructed on land having at least 2% slope, preferably underlaid with sand or gravel.

The most apparent water pollution problems from feedlot operations occur immediately following rains sufficient to cause runoff from the feedlots. Cattle feedlot runoff is a high strength organic waste containing large concentrations of nitrogen and with a high bacteria content. According to research done at Kansas State University, one gallon of feedlot runoff is equivalent to from two to seven gallons of average municipal sewage in terms of pollution load. Runoff from concrete feedlots was found to be approximately twice as heavy as that from nonsurfaced feedlots, due to lack of infiltration.

TRENDS IN MEAT CONSUMPTION, NUMBERS OF CATTLE, NUMBERS OF FEEDLOTS

Consumption of beef and veal has been increasing. By 1980 the domestic demand for beef and veal may increase by about 65% above the 1949-1951 average.

In the 1949-1951 period, total consumption of meat (excluding fowl) in the United States amounted to about 22 billion pounds or about 145.6 pounds per capita as shown in Table III-8. By 1964 consumption had increased to 176.2 pounds per capita; the largest increase occurred in the consumption of beef and veal, up 50% to 106.6 pounds per capita in 1964 compared to 1949-1951.

Increases in the total number of large feedlots are sure to compound pollution control problems in the future. These increases are due to a number of factors, the principal one being economies of scale and advantageous location.

The potential magnitude of the problem can be realized by examining a 1964 study made by the Crop Reporting Board, United States Department of Agriculture, in 32 states.

According to this study, there were 1,635 feedlots marketing 1,000 or more head of cattle in 1964 compared to 1,440 lots in 1962 or an increase of 14%. The same feedlots (less than 1% of the total) marketed 6,912,000 head of cattle in 1964 - 41% of the total that year and 27% more than in 1962.

As of January 1, 1967, a little over 11 million cattle were on feed in the United States. Normally, during January, cattle feedlots are filled to within 50-60% of capacity. Assuming this relationship exists, at any one time feedlots in the United States total about 20 million head capacity. That would mean that feedlot areas in the United States totaled about 138,000 acres or 215 square miles. The 11 million cattle on feed in these feedlots were producing about 700 million pounds of wet manure per day. On an annual basis, this amounts to 255 billion pounds per year scattered over the 138,000 acres. That is a daily manure production of 2-1/2 tons per acre or an annual manure production of 925 tons per acre. About one-half of the wet manure must be cleaned from the pens. The remainder either evaporates, runs into ground water or into surface streams. The waste produced by cattle in feedlots is roughly equivalent to the organic loading of untreated wastes from about 100 million people.

REMEDIES AND COSTS

Considerable research is under way to determine the characteristics of animal wastes and of storm water runoff from cattle feedlots, various means of treating animal wastes, the buildup of nitrates in ground water from feedlot seepage, and the engineering of structures necessary to control feedlot runoff. To date this research has only scratched the surface as far as research needs

TABLE III-8

U. S. PER CAPITA CONSUMPTION OF MEAT AND FOWL, 1949-1951 TO 1964 AND PROJECTIONS TO 1980[1]

Type of Meat	Per Capita Consumption			1980 (Projected)	Decrease or Increase From 1949-1951 to 1980 (Percent)
	1949 to 1951 (Pounds)	1959 to 1961 (Pounds)	1964 (Pounds)		
Beef and Veal (Carcass Weight)	71.2	91.3	106.6	117.0	64.4
Pork (Carcass Weight excluding lard)	70.6	64.9	65.4	58.0	-17.8
Lamb and Mutton (Carcass Weight)	3.8	4.8	4.2	3.5	- 7.7
Chicken and Turkey (Ready to Cook)	24.9	35.7	38.5	45.5	83.0
TOTAL	170.5	196.7	214.7	224.0	31.5

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[1] *Daly*, R. F. *and* A. C. *Egbert*, "*A Look Ahead for Food and Agriculture*," (*Statistical Supplement*) *ERS 277*, *U. S. Department of Agriculture*, *Washington*, *D. C.*, *February 1966*.

are concerned. Continued research is needed to quantify water pollution stemming from animal feedlots and to economically control such pollution.

Estimates of the costs of installing waste treatment facilities vary considerably. The few feedlots equipped with treatment lagoons showed construction costs ranging from $1 to $5 per head capacity. In other words, an operator setting up a feedlot with 20,000-head capacity could possibly spend from $20,000 to $100,000 in construction, excluding buildings. Estimated construction expenditures to control current pollution from large feedlots, with existing technology, would total over $7 million in the 32 states where feedlots are located. Construction includes fencing, grading lots for proper runoff, excavating lagoons, and installing an irrigation system to distribute the effluent to surrounding cropland.

Important factors affecting costs of waste disposal include size and location of feedlot, soil characteristics, and the manner of disposal of solid wastes and effluent. Information is needed on the effects and costs of effluent disposal through irrigation or runoff on ground water supplies. Treatment facilities are few and their effectiveness is poorly understood. For example, in some areas a three-lagoon system is an acceptable waste disposal system for cattle feedlot operations. This type of operation channels the effluent into anaerobic, aerobic, and stabilization lagoons, in that order. The few cattle feedlots using this type of system use the effluent to irrigate cropland. The manure is rich in nutrients, a good soil conditioner, and is sold to surrounding farms for a nominal fee. This system has thus far worked satisfactorily. However, it is too early to recommend this operation for all cattle feedlots.

PESTICIDES IN SURFACE AND GROUND WATERS

Modern pesticides are an important example of the many new synthetic organic chemicals which have helped man to increase the efficiency and productivity of his agricultural and horticultural operations. As would be expected with any new synthetic compound, it is necessary to develop a thorough understanding of the hazards as well as the benefits associated with the use of pesticides. Currently, there is little evidence that the levels of pesticides in surface waters present an acute short-term hazard to man, although little is known about the effects upon humans of long-term, low-level environmental exposure to pesticides. There is, however, considerable evidence that some species, particularly fish, are sensitive to pesticides at very low concentrations.

The major problems regarding pesticides in surface and ground waters relate to their sources, nature and extent, and to the control procedures needed to reduce or to maintain their incidence at tolerable levels.

USE OF PESTICIDES

Total U. S. sales of pesticides in 1966 amounted to an estimated 1.25 billion pounds having a manufacturers' value of around $800 million. Preliminary estimates of production of pesticidal chemicals in the United States during 1966 are:

(1) Fungicides - 177 million pounds
(2) Herbicides - 272 million pounds
(3) Insecticides, fumigants, and rodenticides - 562 million pounds

Included under insecticides, fumigants and rodenticides is a small amount of synthetic soil conditioners. Excluded from the fumigant category are carbon tetrachloride, carbon disulfide, ethylene dibromide and dichloride, which have uses other than as fumigants. The inorganic rodenticides are not included in the rodenticide category.

The Economic Research Service, United States Department of Agriculture, conducted a survey of pesticide use in 1964. Farms with sales of agricultural products of $5,000 or more, in all areas of the United States except the south, were surveyed. In the south (Appalachian, Southeast, and Delta states), farms with agricultural sales of $2,500 or more were surveyed. The farmers' pesticide expenditures by production region and type of farm are listed in Table III-9.

TABLE III-9

U. S. FARMERS' PESTICIDE EXPENDITURES BY PRODUCTION REGION AND TYPE OF FARM, 1964[1]

Region	Expenditure (1,000 dollars)	Type of Farm	Expenditure (1,000 dollars)
Northeast	28,800	Cash grain	75,571
Lake States	42,343	Tobacco	29,603
Corn Belt	87,267	Cotton	85,923
Northern Plains	20,500	Other field crops	15,710
Appalachian	52,693	Vegetable	26,023
Southeast	52,841	Fruit and nut	54,782
Delta States	54,670	Poultry	5,676
Southern Plains	33,593	Dairy	34,897
Mountain	21,311	Livestock	46,391
Pacific	62,222	Ranches	3,675
		General	71,449
		Miscellaneous	6,540
United States	456,240[2]	United States	456,240[2]

[1] *Includes farms with sales of agricultural products of $5,000 or more in all areas of the United States except the South. In the South (Appalachian, Southeast, and Delta States) includes farms with sales of $2,500 or more.*

[2] *An additional estimated $58,062,000 was spent for pesticides on the small farms not included in the survey.*

Source: Adapted from U. S. Department of Agriculture, Economic Research Service, Agricultural Economic Report No. 106, "Farmers' Expenditures for Pesticides in 1964."

The 1964 Census of Agriculture reported the acreage treated, in the United States, for pest control. The data are presented by crop or area, acreage treated, and the percent of the total acreage, under the crop or area, that was treated. In the 1964 Census only the acreage of crops harvested was reported. Therefore, the calculated percentages, based on the acres actually harvested, are likely to appear high. (Table III-10.)

The Plant Pest Control Division, United States Department of Agriculture, cooperates in pest control programs with individual states and with Mexico. Treated acreages in the seven most extensive programs, for 1966-1967 were:

Imported fire ant	9,022,898 acres	Witchweed	531,212 acres
Boll weevil	1,110,324 acres	Gypsy moth	151,900 acres
Grasshopper	1,132,786 acres	Pink bollworm	136,190 acres
Cereal leaf beetle	196,212 acres		

Forest insect control projects conducted by the Forest Service, United States Department of Agriculture, are done in cooperation with individual states and with privately owned timber companies under certain strict conditions. During the years 1966 and 1967, the Forest Service was associated with the control of the following insects on the indicated number of acres:

Project and Location	Acres Treated 1966	1967
Spruce budworm, Idaho, Montana and New Mexico	131,000	-
Fall canker worm, Pennsylvania	1,000	160,000
Pales weevil, North Carolina	4,000	-
Miscellaneous insects	23,500	6,800

Pesticide usage, other than agricultural and forestry, accounts for an undetermined level of potential contamination of the environment. For mosquito-control purposes, pesticides are applied directly to the water or to adjacent areas such as marshes, tide flats, etc. Control of aquatic weeds also involves application of pesticides to water. At present the total amount used in this manner is not available.

PESTICIDE LEVELS FOUND IN WATER

The residual properties and fate of chemicals used in pest control have been the cause of considerable concern in recent years. Whenever pesticides are applied, a certain part of these chemicals may remain as a residue. For purposes of this discussion, we propose to limit the consideration of residues to surface and ground waters. The residues are exposed to attacks by various biological, chemical, and physical agents. The stability or possible

TABLE III-10

PEST CONTROL BY TYPE OF CROP, ACREAGE TREATED, AND PERCENT OF TOTAL ACREAGE TREATED

Crop or Area	Acres Treated	Percent of Total Acreage Treated
Insect and fungus control:		
Grain	16,620,570	42.7
Cotton	8,285,994	21.3
Fruit and nuts	3,296,412	8.5
Hay crops	2,273,438	5.8
Vegetables for sale	1,972,525	5.1
Seed crops and other	6,475,406	16.6
TOTAL	38,924,345	100.0
Weed control:		
Corn	27,130,711	42.1
Small grains	21,107,303	32.7
Cotton	4,046,489	6.3
Pasture and rangeland	3,688,560	5.7
Other	8,527,597	13.2
TOTAL	64,500,660	100.0

Source: U. S. Department of Agriculture report prepared for FWPCA.

translocation of some pesticidal residues within soils or from soils into plants or water, presents problems that require thorough investigation.

Since water moves on and within the soil, its potential effects on the persistence and stability of pesticidal residues should be understood. While insecticidal residues are primarily concentrated in the upper one to two inches of the soil, it has been demonstrated that water in deeper soil strata can be contaminated by these chemicals or their metabolites. Current data indicate that these occurrences are infrequent. The frequency, extent, and duration of such occurrences need study and documentation. A large amount of pesticide pollution of waters in rivers and ponds may occur through the transport of soil particles, to which pesticidal residues are adsorbed, by irrigation runoff, rainfalls or flooding. Pesticides in considerable amount are also transported in solution in water. The fate, persistence, and distribution of pesticides once they reach water should be determined since they potentially affect human and aquatic life.

The known programs for the measurement of pesticides in surface waters are few in number and necessarily limited in scope. Extensive surveillance for chlorinated hydrocarbon pesticides as well as other synthetic organic pollutants has been under way by the FWPCA for several years. In this order of frequency, dieldrin, endrin, DDT, and DDE have been found present in all major river basins. Heptachlor and aldrin have been less abundantly measured, possibly because both compounds undergo chemical change to form epoxides - aldrin changes to dieldrin and heptachlor to heptachlor epoxide.

The potential problem of biological magnification has received considerable attention both in the scientific and lay areas. Biological magnification occurs when organisms at the lower end of the biological scale, become contaminated with pesticides and then are consumed by higher organisms. As this proceeds along the biological scale, it is possible for the pesticide content per organism to increase to the point where intoxication takes place. At present this problem seems to be fairly well limited to the chlorinated hydrocarbon pesticides. There is an urgent need for more intensive investigation of this process to provide information on which to establish water standards in the field of pesticide contamination. The toxicity of many pesticides to various aquatic organisms has been investigated. However, more research needs to be done on the effects of long-term exposure at less-than-lethal levels.

The potential problem of ground water pollution by pesticides is worthy of serious consideration. Present recommendations for the disposal of empty pesticide containers and unused pesticides call for burial in at least 18 inches of soil, in a place where ground water will not be contaminated. It has been a common practice to dispose of empty containers and refuse from manufacturing and formulation plants in this manner. In the case of manufacturing and formulation plants the amount of pesticide-containing refuse to be disposed of can become a major disposal problem. Certain manufacturers have been using incineration techniques to dispose of refuse. Others have maintained "graveyards" where the material is buried.

As early as 1945 the United States Department of Agriculture cooperated with the Fish and Wildlife Service to study some of the biological effects of forest insect control. This was a study of modest proportions involving more than 20 experimental areas, using varied dosages of DDT to determine its effect on various forest types and forest pests. From this modest beginning, monitoring programs have increased in magnitude and sophistication. Federal, State and private agencies cooperate in monitoring insect control programs. Equipment unknown on the market until recent years, now is available for measuring residues in parts per billion, or even parts per trillion. One might well ask if there were insecticide and pesticide residues in our waters a number of years ago that now could be measured but which were not detectable with equipment and methods of a decade ago.

Forest lands comprise one-third of the total area of the United States, receive one-half of the total precipitation, and yield about two-thirds of the streamflow. Forest lands annually receive more than twice the precipitation falling on other lands and yield about 16 inches of runoff per year, four times that from other lands. Thus forest lands provide most of the Nation's water supply.

In 1962, 1.7 million pounds of insecticides were applied to about 1.8 million acres of forest land. In addition, about half this amount of herbicides and a small amount of other pesticidal chemicals were used. Insecticides used in 1962 on forest lands represented about 1% of the total poundage of insecticidal chemicals distributed in the United States. Thus, the rate at which pesticides are used in the forest is substantially lower than in most other land classes. Only about 5% of the Nation's forest lands have ever been treated with an insecticidal chemical.

Most of the studies made following forest spraying have dealt with adverse effects of initial application on fish and wildlife. Very little is known of the long-term impact of forest pesticide use on water quality.

REMOVAL OF PESTICIDES FROM WATER

Numerous studies have shown that repeated application of pesticides, particularly of the chlorinated hydrocarbons, has resulted in residues of some of these compounds being found in soil layers corresponding to plow and cultivation depths. These compounds are generally resistent to biological degradation. The extended persistence of these compounds has increased the chance of water contamination. Current knowledge as to the extent and amount of pesticide residues in water resources is meager, and knowledge about the significance of these residues and their effect on water supplies even more so. The committee which reviewed and updated the USPHS Drinking Water Standards in 1962, concluded that the information available at that time was not sufficient to establish specific limits for pesticidal chemicals in drinking water. Only the concentration that will produce a perceptible odor in water has been determined for several pesticides. (Table III-11.)

A study conducted by FWPCA personnel at the Taft Sanitary Engineering Center assessed the effect of various treatments on concentrations of dieldrin, endrin, lindane, DDT, 2, 4, 5-T and parathion from water. The study indicated that, while each part of the treatment plant may have potential for reducing certain pesticides, no effective practical treatment is known for large volumes of water containing pesticides.

COSTS

Although more needs to be done to assure long-term safeguarding of the environment from pesticidal residues, the actions to reach these goals cannot be defined precisely enough to assess the costs at this time.

TABLE III-11

THRESHOLD ODOR CONCENTRATIONS OF PESTICIDES AND SOLVENTS IN WATER

Pesticides	Threshold Odor Concentration in ppm
Parathion (technical grade)	.003
Parathion (pure)	.036
Endrin	.009
Lindane	.330
Formulation components	
Sulfoxide (synergist)	.091
Aerosol OT (emulsifier)	14.600
Commercial Solvents	
Deodorized Kerosene	.082
Solvent 1	.016
Solvent 2	13.900
Solvent 3	.090

Source: *U. S. Department of Agriculture report prepared for FWPCA.*

NUTRIENT ENRICHMENT OF LAKES AND STREAMS

This section discusses the contribution of agricultural land through the processes of runoff and deep percolation, erosion, and animal feeding to the mineral enrichment of water. The inadequacies of present information are noted, and control measures that can be instituted are suggested.

LAND RUNOFF

All plant and animal life, whether on land or in water, requires mineral nutrients to grow and reproduce. On land, agriculture and agricultural research have been concerned for centuries with providing such nutrients in proper amount and balance for good crop yields, proportionately nutritious to people and animals. In water, until about two decades ago, we depended on natural runoff to supply the necessary minerals to the aquatic life that serves as food for fish, shellfish and crustaceans harvested by man. Only recently have we learned how to enrich or fertilize pond waters and lakes artificially to increase their productivity. Now we are finding that water can be excessively and unintentionally enriched - to the point where "nuisance" blooms of algae, noxious odors, and excess growth of water weeds degrade the quality of the water. This water enrichment process - eutrophication - is desirable up to a point, but carried too far becomes pollution. Nutrient accumulation is part of the natural geological process in the aging of a lake, but accelerated by man, it leads to quick "death" of the lake.

Enrichment of stream and lake water can come from raw sewage, the effluent of sewage treatment systems, runoff from city streets, the wastes of industry, and the runoff, leachate, and sediments from agricultural land.

At least 12 mineral elements are needed to sustain life in a pond or lake, but only two - nitrogen and phosphorus - receive much attention, for they are the ones that control or limit the growth of plant life. The others are generally present in such concentrations relative to plant requirements that they may have little or no effect on the amount of growth. Examples are known of lakes deficient in molybdenum and iron for the optimum growth of phytoplankton, but such instances are rare.

The problems associated with excessive nutrient accumulation in lakes and streams are excessive growth of algae, mosses, and bottom-rooted grasses along the shores. Growth of actinomycetes on the algae and the decomposition of organic debris in the bottom muds produce offensive odors. Decomposing dead algae and other water plants deprive fish of oxygen. The desirable sport and food fish are replaced by less desirable scavenger species. The oxygen deprivation may produce greatest loss of fish in winter when the lake is frozen over. Fishing lines, boat propellers, and water skiers get fouled up in the excessive vegetation. Shoreline properties decline in value. Many examples of such lake deterioration can be cited - Lake Erie, Lake Washington, the Potomac estuary, to name a few.

The U. S. Department of Agriculture, as of June 30, 1965, has given technical and/or cost-sharing assistance in constructing 1,420,733 farm ponds. The estimated losses in potential uses of these ponds caused by aquatic weeds for the period 1951-1960 was $27,320,000 annually. In a farm pond, the nutrients have to come from the land, fertilizers applied to land, the farmstead, or excrement of migratory waterfowl.

Whether phosphorus or nitrogen is most limiting to growth depends on the local situation. Evidence from Lake Erie indicates that there may be seasonal variations when an element limits growth. Chemists know that they can often obtain some growth of valve-plugging organisms even in distilled water lines. No limit can be set for an element at which there will be no growth, for plants have an enormous capacity to accumulate ions from extremely dilute solutions. However, we are concerned with the levels that are associated with objectionable growths in water. Mackenthun[7] (1965), based on a review of the literature, indicated that 0.015 ppm of total phosphorus and 0.3 ppm inorganic nitrogen in the spring are associated with dense algae blooms later in the season. He recognized that many considerations such as the rate of water flow, the composition of the inflow, and the rates of decomposition and release of nutrients in the bottom muds can modify these values.

Increasing use of fertilizers on farms has received much of the blame for accelerated enrichment of surface and well waters. For example, the total U. S. production of anhydrous ammonia in December 1966, was over one million tons. This is more than the total nitrogen fertilizer consumption in any year before 1948. In 1940, U. S. farmers used about 380,000 tons of nitrogen as fertilizer. In 1966, farm use amounted to over 5-1/4 million tons, almost a 14-fold increase. Hence, it is easy to conclude that accelerated eutrophication is a modern problem and that fertilizers are largely responsible.

However, there is considerable evidence that ground and well waters, particularly in the arid and semi-arid West, contained considerable nitrate before commercial fertilizers were used to any appreciable extent. The accumulation of "niter" spots in the Arkansas Valley of Colorado, studied in the 1920's and 1930's is classic. This accumulation, once blamed on nitrogen fixation, was later shown to be a problem of accumulated nitrates, along with other salines. Unirrigated, uncropped soil in the San Joaquin Valley of California was core-drilled to a depth of 50 feet and yielded 1,400 to 1,800 ppm nitrate-nitrogen calculated on the basis of the soil solution. These profiles below about four feet were dry, with soil water suctions in the range of 15 to 80 bars. At this suction, little downward movement of nitrate could occur, but when the soil was irrigated, nitrate moved downward with the wetting front. An accumulation of nitrate-nitrogen was reported under dryland unfertilized fields in northeastern Colorado. A marked zone of nitrate accumulation occurred below the rooting depth of crops. Cropped profiles averaged 208 pounds of nitrate-nitrogen per acre to a depth of 22 feet, whereas dryland native pasture land averaged only 72 pounds to the same depth.

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[7] Mackenthun, K. M., "*Nitrogen and Phosphorus in Water and An Annotated Bibliography of Their Biological Effects*," USPHS Pub. 1305, 1965, p. 111.

Nitrates in water are actually a very poor measure of the enrichment of water. Aquatic plants readily remove nitrate from water. Depletions of nitrate in water at successive downstream sampling stations on a given river are frequently noted. High accumulations of nitrate in surface waters is good evidence that some other condition, probably a limitation of phosphate, is inhibiting the use of nitrate by aquatic plants.

USE OF FERTILIZER NITROGEN

In 1940, total nitrogen in fertilizers applied to U. S. farms was less than 500,000 tons. In 1964, about 4.5 million tons of nitrogen were applied, and there is no indication that the rate of increase is slowing.

There is little point in citing average uses of nitrogen for different crops and soils because the averages for the U. S. as a whole or regionally within the country presently represent suboptimum levels in terms of crop response. Within each region or State, levels of nitrogen fertilizer use range from far less than adequate to excessive. With a normal frequency distribution, one might expect that one-third to one-half of a given crop acreage receives near-adequate fertilization, with the remainder divided between suboptimal and excessive use.

The goal in nitrogen fertilization is to minimize the amount of nitrogen that must be applied to achieve the desired crop response. But with low-cost nitrogen fertilizer, its use is being increasingly geared to producing maximum yields in the sense of nitrogen not being a limiting factor.

Considering only the crop receiving the fertilizer, data support the conclusion that the efficiency range is broad, from about 25% to 75%. A level of 40% to 50% can be expected when timing of application is coordinated with crop demands for nitrogen.

It is well established that nitrogen fertilization for maximum yield contributes an excess of nitrogen to the immediate environment. In the vast amount of field and associated laboratory research, little specific information has been provided regarding the fate of the excess nitrogen under conditions of high fertilization.

During decomposition of root residues produced under conditions of nitrogen abundance, substantial amounts of the nitrogen may be mineralized readily, thus augmenting the pool of fertilizer nitrogen remaining in the soil. In well-aerated agricultural soils, most of the mineral nitrogen is converted to nitrate, in which form it readily moves downward in percolating water. If the oxygen level is adequate, the nitrogen persists as nitrate, and remains mobile within and below the root zone. Studies on sources of nitrate in ground waters have been few and not very definitive in that not all possible sources, i.e., corrals, farmland, sewage disposal fields, and cesspools were considered.

Under humid conditions it is known that large losses of nitrogen by leaching can occur if nitrogen is applied in the fall and if winters are mild. Too many studies on the recovery efficiency of fertilizer nitrogen conducted under conditions where leaching losses were thought to be minimal have given insufficient attention to the downward movement of nitrate below the root zone. The low recoveries often noted were presumed due to denitrification. Unfortunately, there are no direct quantitative measurements in the field of the magnitude of denitrification.

PHOSPHORUS

Phosphorus and the Fertility of Natural Waters

Phosphorus is generally considered to be the critical element in controlling the fertility of natural waters. The critical concentration limiting the growth of blue-green algae, whose appearance frequently indicates any undesirable increase in fertility, is about 0.01 ppm (of phosphorus). Concentrations of 0.05 ppm provide an excellent medium for profuse growth, and at levels above this, the population is controlled by other factors such as light penetration. In most uncontaminated waters, phosphate concentrations are about 0.01 to 0.03 ppm which is close to the critical level. Relatively small increases in concentration often have noticeable effects in the growth of both algae and aquatic weeds that cause severe water management problems.

Sources of Phosphorus

Although 70% to 80% of the phosphates produced in the United States are used as fertilizer, they have many industrial and domestic uses, the most prominent being in synthetic detergents. Between 15% and 40% of the weight of such materials, depending upon their use, is composed of phosphate salts.

Statistics on phosphorus consumption are complex, but a reasonable estimate of the amount used for purposes other than as fertilizers can be made from the data on the annual production of electric furnace phosphorus. Table III-12 shows that close to 80% of this material has gone into uses other than fertilizer since the mid-1950's.

Table III-13 shows the relative amounts of phosphorus consumed in both fertilizer and non-fertilizer forms in the United States since 1950. The amount of non-fertilizer material is based upon the furnace acid figures of Table III-12. These data show that non-fertilizer consumption has increased more rapidly, and is now about 23% of the total. Since 1950 there has been almost a three-fold increase in per capita consumption of phosphorus.

Phosphorus use in detergents is particularly important because these compounds are completely water soluble and pass directly into sewers and drainage waters where they are fully available to plants. Unless sewage treatment specifically designed to remove phosphate is applied, urban areas will contribute available phosphorus at an annual rate of about five tons per 1,000 persons in the form of sewage effluents containing concentrations up to five ppm. The amounts of phosphorus-free water needed to dilute this to tolerable levels are rarely available.

The fraction of fertilizer phosphorus moving directly into natural waters is very small. Even where highly soluble salts are used, they are rapidly converted to insoluble forms in the soil. In time this phosphorus becomes distributed through the topsoil, but many studies have shown that downward movement below plow depth is slow. Over 95% of phosphorus applied remains permanently in the top six to nine inches of the soil. The strong adsorption capacity of the subsoil reduces the phosphate content of the soil water to 0.005 ppm or less and, under normal agricultural conditions, the amount in drainage water is insufficient to support algal growth. A notable exception is found where large amounts of phosphorus are used on well-drainged, irrigated soils. Average concentrations of 0.08 ppm have been observed under such conditions in California's San Joaquin Valley.

Phosphorus and Soil Erosion

The most direct way in which agricultural phosphorus moves into drainage waters is by erosion of the soil into which it is adsorbed. The phosphorus content of agricultural soils varies widely, but the largest amounts, ranging from 800 to 2,700 pounds per acre to a six-inch depth, are found in the Western States. The average rate of application on cropland in the United States is close to 20 pounds per acre, although certain crops, notably tobacco and potatoes, average two to three times this amount.

Several studies have shown that phosphorus losses from cropland are caused entirely by erosion. Table III-14 shows that a loss of four tons per acre of soil containing 1,000 ppm of phosphorus - which may occur in soils in which cotton or corn is grown - will represent a loss of eight pounds of phosphorus

TABLE III-12

U. S. PRODUCTION OF PHOSPHORIC ACID IN THOUSAND TONS OF ELEMENTAL PHOSPHORUS

Year	Total	Furnace Acid		Wet Process Acid	
		Total	Non-fertilizer	Total	Non-fertilizer
1965	1,707	441	358	1,266	94
1964	1,434	440	356	994	92
1960	922	333	-	589	-
1955	556	235	207	321	52
1950	254	128	-	126	-

Source: Department of Commerce Data

TABLE III-13

U. S. CONSUMPTION OF PHOSPHORUS

Year	Phosphorus Consumed as:		Percent as Non-fertilizer	Non-fertilizer Consumption lbs./person/yr.
	Fertilizer 1,000 tons	Non-fertilizer 1,000 tons		
1965	1,520	441	23	4.5
1964	1,460	440	23	4.6
1960	1,112	333	23	4.6
1955	987	235	19	2.8
1950	841	128	13	1.6

Source: Department of Commerce Data

TABLE III-14

EROSION OF SOIL AND PHOSPHORUS FROM FIVE EXPERIMENTAL PLOTS OF DIFFERING SLOPES ON DUNMORE SILT LOAM, VIRGINIA

Plot Slope (Percent)	Average Annual Soil and Phosphorus Loss Over 3-Year Rotation			Maximum Annual Soil Loss
	Soil	Total Phosphorus		
	(tons/acre)	(lbs./acre)	(lbs./ton of soil)	(tons/acre)
5	4.38	8	1.8	6.5
10	8.25	10	1.2	14.0
15	12.42	13	1.0	24.5
20	11.55	13	1.1	19.7
25	19.50	26	1.3	35.5

Source: U. S. Department of Agriculture report prepared for FWPCA.

per acre a year. Under high erosion conditions this can increase to the order of 30 to 50 pounds. Since this will be largely adsorbed in the soil colloids, only a fraction of this will be available for plant growth. If this fraction is assumed to be 10%, then figures indicate that fertilizer and soil phosphorus may be contributing to available phosphorus in lakes and rivers at about one to five pounds per acre per year. This estimate agrees substantially with measurements of the phosphorus content of surface drainage waters on the Kaskaskia River in Illinois which showed losses ranging up to 14 pounds per acre per year with a mean value of about 2.5.

In addition to phosphorus carried into streams by soil erosion, significant contributions may be made by leaching or by surface erosion of animal manure from stockyards or manure piles. The phosphorus contents of some animal manures are summarized in Table III-15, and average amounts excreted annually per 1,000 pounds body weight of various animals are presented in Table III-16, page 240. Pollution from stockyards is of particular importance because feedlots represent points of high local input, especially where they are situated near streams to take advantage of the water supply. The movement of phosphorus from animal wastes may then be a continuous process as opposed to the sporadic nature of the movement of phosphorus by soil erosion. Animal input may be highest when erosion is least, as when wastes are washed into streams over frozen ground in the winter. It is estimated that agricultural land contributed 45% of the phosphorus input to Lake Mendota, Wisconsin, and the chain of lakes associated with Lake Mendota. Seventy-five percent of this phosphorus came from runoff in the spring from an area where heavy manure applications were made on frozen soil.

On the basis of the foregoing data it is possible to make some general comparisons. A loss of five pounds per acre from a fertile soil means that the output from one square mile is about the same as that from a community of 700 people, or a stockyard containing 200 cows, each of 1,000 pound-weight. These figures represent totals and not effective amounts, which depend upon the chemical forms in the various cases.

The Chemistry of Phosphorus in River Water

Direct measurement of the total phosphorus concentration, including that on the suspended mineral material, cannot be regarded as a useful measure of the amount available for plant growth. Measurements of the rate at which equilibrium is established between the dissolved and adsorbed forms of phosphorus in the soil show that complete equilibrium is never reached and the bulk of the soil phosphorus is very inert. The most reactive part, reaching equilibrium within a few days, is usually less than 5% to 10% of all the phosphorus present. The amount of biologically active phosphorus present in stream water carrying a significant load of sediment is probably a small fraction of the total. Water containing 0.01% by weight of sediment, which itself contains 1,000 ppm of phosphorus, would have a minimum total concentration of

TABLE III-15

PHOSPHORUS CONTENT OF ANIMAL MANURES OF VARIOUS ORIGINS

Source	Range of Phosphorus Content of Animal Manures (% dry weight)		
	Total	Inorganic*	Organic
Chicken	0.73 - 2.99	0.39 - 2.42	0.34 - 0.57
Hog	0.27 - 0.77	0.19 - 0.61	0.08 - 0.16
Horse	0.26 - 0.35	0.20 - 0.24	0.06 - 0.11
Cow	0.43 - 0.73	0.26 - 0.64	0.17 - 0.09
Sheep	1.19	0.75	0.44

Inorganic defined as that extracted in 10% trichloracetic acid in three hours.

Source: U. S. Department of Agriculture

0.1 ppm, while the amount in true solution might be 0.01 ppm or less. Little information is available about the contribution made by suspended phosphate to the biological activity of river water. The matter is important, because in lakes and still streams, settling sediment will carry considerable amounts of phosphorus that may be returned to the upper water when the sediment is disturbed under storm conditions.

Up to 20% of the total phosphorus in a surface soil may be present in organic forms, although this fraction may vary a good deal with the locality, type and management history of the soil. Table III-16 shows that considerable amounts of phosphorus derived from animal wastes may also be organic. In undisturbed soil, the organic fraction does not readily reach equilibrium with that in true solution, and is not immediately available for plant consumption, but abrasive action of eroding materials and the stirring action in streams may tend to increase its availability. Little information is available on the biological activity of organic phosphates in streams, and new analytical procedures are needed to reveal the significance of this activity.

TABLE III-16

AMOUNTS OF PHOSPHORUS EXCRETED ANNUALLY BY 1,000 POUND WEIGHT OF VARIOUS ANIMALS

Source	Annual Excretion of Phosphorus (lbs. P/1,000 lb. wt. of animal)
Cow	17
Horse	19
Sheep	19
Poultry	30
Swine	45

Source: U. S. Department of Agriculture

COSTS

No estimate has been made of the cost of providing adequate safeguards against excessive nutrient runoff. Current procedures depend largely upon educational programs that encourage application of nutrients to the soil on the basis of tested need, thus avoiding the hazard of "luxury" over-fertilization. As new research data identify the sources and amounts of nutrient runoff, and as new technology provides nutrients in forms that will avoid displacement, cost estimates can be developed.

IMPACT OF IRRIGATION ON SALINITY OF SURFACE WATERS

Salinity of surface waters refers to their total soluble salt content, mainly of chlorides, sulfates, and bicarbonates of calcium, magnesium, and sodium. The amounts and proportions of these constituents vary not only from river to river, but from reach to reach of a single river. This section discusses the impact of irrigation agriculture on total salinity, and specific salt composition of rivers, and some measures for control of salt-degraded water.

Dissolved salts derive ultimately from weathering of rock and solubilization of soil minerals. Immediate salt sources vary. Even rainfall contributes some miniscule amount of salt to surface waters, though the contribution of seawater salts and dust-borne salts to surface water salinity is generally minor (probably 10% or less). Rainwater percolating through soils carries additional salts into rivers and lakes. These salts are produced by weathering of soil minerals, and the process is the principal natural source of salinity in surface waters.

In some areas, salt beds or saline strata of geologic origin may contribute especially high salt concentrations not only to percolating rainwater, but to rivers and streams flowing across their surface.[8] In humid zones the salinity of surface water is generally low because soils have been leached for eons by abundant rainfall. In arid and semi-arid zones soils contain larger amounts of salts, and surface waters generally have higher salt concentrations. (The acreage of irrigated farmland is shown in Table III-17.)

It is important, then, that irrigation, subject to mineralization, is most necessary in arid areas, for irrigation itself is an unvarying source of salinity in waters. The well documented salinity of the Colorado River, for example, may be traced - even as far upstream as Hoover Dam - in large part to irrigation. (Table III-18.)

Although not conclusive, evidence presented in Table III-19 shows that the salinity problems in the Colorado, North Platte, Arkansas, and Rio Grande areas did not necessarily originate with the extensive development of irrigation projects, but that salts were present in substantial amounts over 60 years ago. Analyses of various chemical constituents of single samples of water shows the Colorado River had 833 ppm of dissolved salts at Yuma, Arizona in 1893, and that the Arkansas River content ranged from about 1,100 to 1,400 ppm during September and October in 1909. It is clear, however, that the onset of extensive irrigation has intensified the salt problem; for the

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[8] McNeal, B. L. and Bower, C. A., Evaporates in Soils, Chapter 8 in "Weathering of Rocks and Minerals in Soil Genesis", Volume 1 of Encyclopedia of Soil Science.

TABLE III-17

ACREAGE OF IRRIGATED LAND IN FARMS[1/]

Water Resource Region	Acres (1,000)
North Atlantic	203
South Atlantic-Gulf	560
Great Lakes	82
Ohio	30
Tennessee	13
Upper Mississippi	55
Lower Mississippi	625
Souris-Red-Rainy	9
Missouri (Arid)	5,802
Arkansas-White-Red (Arid)	2,806
Texas-Gulf (Arid)	4,168
Rio Grande (Arid)	1,638
Upper Colorado (Arid)	1,361
Lower Colorado (Arid)	1,219
Great Basin (Arid)	1,426
Columbia-North Pacific (Semi-Arid)	5,014
California (Semi-Arid)	7,627
TOTAL	32,638

[1/] *Tabulated by Water Resource Regions from the 1959 Census of Agriculture.*

TABLE III-18

INCREMENTAL SALT CONCENTRATION ATTRIBUTABLE TO SPECIFIC SOURCES, COLORADO RIVER AT HOOVER DAM[1/]

(1942-1961 Period of Record Adjusted to 1960 Condition)

Factor	TDS* Increment, Mg/L
Natural Sources	
Diffuse Sources	274
Point Sources (mineral springs, wells, etc.)	69
Irrigation	
Consumption	88
Leaching	165
Municipal and Industrial Sources	10
Water Exports	22
Evaporation and Phreatophytes	97
TOTAL	725

[1/] *Based on data from: USGS Professional Paper 441, Water Resources of the Upper Colorado River Basin, 1965; USDI, Progress Report No. 3, Quality of Water, Colorado River Basin, January 1967; FWPCA records on open file.*

* *Total Dissolved Solids*

TABLE III-19

HISTORIC WATER QUALITY DATA FROM FOUR WESTERN RIVERS[1]

Date	Parts Per Million of TDS	Location
	Colorado River	
1893	833	Yuma, Arizona
	North Platte River	
Sept. 1906	262	North Platte, Nebraska
Oct. 1906	361	Columbus, Nebraska
Oct. 1906	265	Premont, Nebraska
	Arkansas River	
Sept. 1907	1,079	Great Bend, Kansas
Sept. 1907	1,105	Arkansas City, Kansas
Oct. 1907	1,418	Deerfield, Kansas
	Rio Grande River	
1893-1894	399	Mesilla, New Mexico
Sept. 1905	746	Laredo, Texas

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[1] Clark, F. W., *The Composition of Rivers and Waters of the United States*, USGS Professional Paper 135, 1924.

past six years the Colorado River at Yuma, Arizona, has averaged about 2,300 ppm (total dissolved solids). The difference between 833 and 2,300 TDS is probably due to irrigation return water.

Table III-20 indicates about a 40-fold variation in salt content of these rivers. A river, such as the Rio Grande, may have low salinity in its headwaters, but build up to a high salinity at its mouth. This increase in salinity results in part from the inflow from saline tributaries, from removal of salts from irrigated lands, and from the evaporative loss of water due to irrigation with resultant concentration of salts in the smaller residual volume.

Data in Table III-20 also show that irrigation and drainage waters from selected irrigation districts vary in electrical conductivity, and hence salinity. In all cases, the salinity of drainage water is higher than that of the irrigation water. However, the ratio between the two concentrations is not constant. It varies from about a twofold increase in most instances to a tenfold increase in the case of the tile drainage water in California's Imperial Valley. Rate of evapotranspiration, level of reuse, degree of segregation of saline return waters, and leaching rates all affect the ratio.

For the chemical composition of some river waters used for irrigation, see Table III-21.

SIGNIFICANCE OF WATER QUALITY DEGRADATION AS THE RESULT OF IRRIGATION

Increased salinity is an inescapable consequence of irrigation. Unlike most uses, irrigation involves actual consumption of water rather than its use and subsequent discharge. Up to 70% of applied irrigation water is taken up by the plant life or is evaporated. (The more efficient the application of water, the higher the coefficient of evapotranspiration.) Little, if any, of the dissolved salts carried in irrigation water is used by the plant life. Each use of water in irrigation increases the concentration of salts by reducing the volume of the carrying liquid; (e.g., if water with 100 ppm of TDS is applied and the rate of evapotranspiration is 50%, then half as much drainage water returns to the stream as was diverted, but it contains the original quantity of salts, so that the concentration of TDS in the irrigation return water will have been increased to 200 ppm). Increasing further the potential salinity of irrigation return water is the fact that one of the functions of irrigation is to flush excess salts away from the root zone of growing plants. Arid soils tend to be highly mineralized requiring extensive flushing, so that irrigation of such soils results not only in a reduction of carrying water, but in a net increase in the gross volume of salts. (The earlier illustration, where a 50% loss of water involved a 100% increase in TDS concentrations, assumed the most favorable situation, existence of a salt "balance" with no pick up of soil salts during irrigation. To carry the illustration

TABLE III-20

COMPARISON OF THE SALINITY IN IRRIGATION AND DRAINAGE WATERS FROM SELECTED IRRIGATION DISTRICTS

Irrigation District	Salinity (Mineralization as Electrical Conductivity)	
	Irrigation Water	Drainage Water
Middle Rio Grande Valley, Albuquerque Division[1]	481	1,070
Lower Rio Grande,		
Rincon, Division[1]	834	1,480
Mesilla Division[1]	869	1,410
El Paso Division[1]	1,200	3,680
Pecos River, Carlsbad Area[2]	4,360	7,800
Colorado River Water, Meloland Imperial Valley, California[3]	1,120	11,770
Wapato Project, Washington (Yakima River water)[3]	137	296

[1] U. S. Geological Survey Water Supply Paper 839, "Quality of Water of the Rio Grande Basin Above Ft. Whitman, Texas," 1938.

[2] U. S. National Resources Planning Board, Pecos River Joint Investigation, Reports of Participating Agencies, 1942.

[3] Unpublished Data, U. S. Salinity Laboratory, Riverside, California.

TABLE III-21

CHEMICAL COMPOSITION OF SOME RIVER WATERS USED FOR IRRIGATION IN WESTERN UNITED STATES[1]

River	Location	Date Sampled	Mineralization as Electrical Conductivity	Dissolved Solids (ppm)
Missouri	Williston, North Dakota	11/29/45	838	574
Yellowstone	Miles City, Montana	7/22/48	548	368
North Platte	Wyoming-Nebraska lines	10/8/45	828	565
South Platte	Englewood, Colorado	7/11/44	406	246
Platte	Aurora, Nebraska	7/21/51	800	571
Arkansas	La Junta, Colorado	7/21/44	1,210	981
Arkansas	Ralston, Oklahoma	8/16/44	1,670	967
Canadian	Conchos Dam, New Mexico	6/3/43	844	586
Rio Grande	Otowi Bridge, New Mexico	6/46	340	227
Rio Grande	El Paso, Texas	6/46	1,160	754
Rio Grande	Roma, Texas	6/46	607	380
Pecos	Carlsbad, New Mexico	1945/46	3,210	2,380
Gila	Florence, Arizona	4/10/34	1,720	983
Salt	Stewart Mountain Dam, Arizona	3/8/34	1,210	664
Colorado	Yuma, Arizona	3/21/43	1,060	740
Sevier	Central, Utah	6/5/49	580	338
Sevier	Delta, Utah	6/3/49	2,400	1,574
Weber	Ogden, Utah	10/7/49	510	308
Humboldt	Rye Patch, Nevada	8/48	1,173	658
Sacramento	Tisdale, California	8/15/47	162	108
Kern	Bakersfield, California	9/28/44	234	152
Columbia	Wenatchee, Washington	11/25/35	151	78
Snake	Minidoka, Idaho	1948/49	410	246
Payette	Black Canyon, Idaho	1948/49	100	60
Rogue	Medford, Oregon	9/13/32	108	72

[1] *Data from Table 12, page 77 of Agricultural Handbook 60, "Diagnosis and Improvement of Saline and Alkali Soils," 1954.*

one step further, assume that a volume of salt equal to one-half the volume borne by the applied waters is flushed from soil and dissolved in the irrigation water; then the return flow would have a TDS concentration three times that of the originally diverted water, or - in the illustration - 300 ppm.) When the return flow merges with the receiving river, the net result is an increase in salinity that can affect all downstream water users. Because the mechanism is invariable, cumulative salinity is progressively greater with each reuse of irrigation water.

Salinity is generally regarded as excessive for domestic use when total salt content exceeds 500 ppm, although more saline water is sometimes used. Even salt-sensitive crops can increase the salinity of return flows to five times this value. Dilution in the river may partially correct this effect, but reuse of the river water for irrigation will ultimately reduce the water volume and increase salinity.

Industrial uses of water are so varied that no single salinity limit for general industrial use can be given. When high quality water is required, as for boiler water, paper manufacture, or food processing, the increase in salinity caused by irrigation agriculture in many cases impairs the suitability of the river water.

Along many western rivers, water is reused by several irrigation districts along the river. Downstream projects must generally use more saline waters than those available to upstream users. Frequently, dilution of return flows in the river reduces salinity sufficiently to permit repeated use of the river water. However, it should be pointed out that downstream users are not necessarily benefited by the volume of return flow waters added to the river by upstream irrigation districts. For example, if an upstream district has used its irrigation water with maximum efficiency, the return flow will be as concentrated as the particular crops grown in that district can make it without damage to the crops. Only by the growth of more salt-tolerant crops can this return flow be utilized further. If more salt-tolerant crops are not grown in the downstream projects, the return of such intensively used water to the river contributes no usable water to those downstream projects. This results because the salt carried in the return flow from the upstream district must reappear in the same water upon reuse downstream. In such cases, downstream users are penalized because the additional volume of water with no reuse potential must be carried through the project and drained. If, on the other hand, crops five to ten times as salt tolerant are grown downstream, then a correspondingly higher salt concentration compared to the upstream return flow water can be tolerated.[9]

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[9] Bernstein, Leon, "Reuse of Agricultural Wastewaters for Irrigation in Relation to the Salt Tolerance of Crops", Proc., Symposium on Agricultural Wastewaters, Report No. 10, Water Resources Center, University of California, 1966, pp. 185-188.

Three choices are available for controlling natural situations marked by excess salinity, such as those occurring in the Red River and Arkansas River Basins: divert the flow of saline springs around the points where waters are diverted for beneficial uses; create a head of water over the outlets of saline springs to stop their flow; and cut off by diversions or by surface sealants the supply of percolating water. The last procedure has a twofold advantage. Not only is the salt source avoided, but the yield of fresh water is sustained or increased.

Areas having concentrated deposits of salts in underlying strata could be avoided by excluding them from irrigation developments. Canal routes may be selected to avoid such deposits or the canals can be lined.

Another possible source of salts in return flows from irrigation districts is highly saline shallow aquifers underlying an irrigated area. A high water table often develops in such areas because of restricted natural drainage, and drainage systems usually are needed to discharge the extra water applied to satisfy the leaching requirement for the system.

INCREASING THE FLOW OF WATER WITH WATER OF LOWER SALT CONCENTRATION

Water Harvest

The feasibility of increasing runoff from salt-affected areas by reducing infiltration, utilizing soil surface sealants, offers one possibility of collecting and releasing high quality water for control of natural salt accumulations. Instead of having natural flow of poor quality from salt-contributing areas such as the extensive Mancos shale deposits in Wyoming and Colorado, the soil surface could be sealed using chemical or physical barriers that cause essentially 100% runoff. Sodium chloride to disperse the soil surface, cut back asphalt emulsion as a soil sealant, and plastic membranes have been effective on small research plots.[10]

Import of Water

Attention is being given to inter-basin transfer of water to reduce salt concentrations by dilution during critical periods of flow and to provide water supplies. Imported water would often permit greater flexibility in regulation of stream flows and diversions, particularly as related to the water requirements of irrigated agriculture, but only to the extent such water was not used to provide additional irrigation.

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[10] *Myers, L. E., "Water Harvesting," presented at Nevada Water Conference, 17th (Carson City, Nevada), 1962, p. 14.*

Increasing Precipitation by Weather Modification

Weather modification to increase water supplies in arid regions has received much research attention during the past decade. Considerable knowledge has been gained about the physics of cloud formation, and the potential contribution that atmospheric water may provide in augmenting natural precipitation. It appears that water supplies in mountainous areas might be increased 10% to 15% by seeding storms with silver iodide to increase snow accumulation and ultimate runoff.[11]

Proposed projects for major inter-basin transfers of water and the seeding of clouds, however, are costly, create legal and political problems, and involve unmeasured ecological hazards.

REDUCTION OF EVAPORATION AND TRANSPIRATION LOSS

Agriculturally nonbeneficial use of water by phreatophytes or water-loving plants growing adjacent to river channels, canals and drains amounts to an estimated 25 million acre-feet of water annually in the Western States.[12] Salt cedar is the most common phreatophyte in the Southwest and requires from five to nine acre-feet of water per acre annually. The obvious solution to the problem is eradication, a practical, but costly, way to increase river flow and thereby reduce salt concentration.

Another major loss of water in the 17 Western States occurs by evaporation from freshwater and inland saltwater bodies. It is estimated that about 23 million acre-feet of water is lost annually through evaporation from freshwater areas and another 17.5 million acre-feet is lost from inland saltwater areas.[13] The flurry of research activity in the past decade to explore the effectiveness of monomolecular films (hexadecanol and octadecanol) on water surfaces to reduce evaporation losses has almost ceased. Though these chemicals form an effective barrier to evaporation from water surfaces, weed and algae growth and wave action limit practical utility. (Results indicate that evaporation can be reduced by as much as one-third under ideal conditions.) Work is continuing[14], but the use of chemicals to suppress evaporation appears to have limited application. Exploratory work with floating plastic membranes shows promise in reducing evaporation as well as controlling aquatic growth.

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[11] *"Irrigation of Agricultural Lands," Monograph No. 11, 1967, pp. 45-46.*

[12] *Robinson, T. W., "The Phreatophyte Problem," In Symposium on Phreatophytes, Pacific Southwest Interagency Committee, 1958, pp. 1-11.*

[13] *Garstka, Walter U., "Evaporation and Its Reduction," Proc. International Seminar on Soil and Water Utilization, South Dakota State College, Brookings, South Dakota, July 1962, p. 74.*

It is estimated that one-fourth to one-third of all water diverted for irrigation purposes is lost in conveyance. U. S. Bureau of Reclamation records for 46 projects show that 15.7 million acre-feet of water is diverted annually. That lost to seepage represents 3.9 million acre-feet and evaporation losses from canals accounts for another 1.0% to 1.5% of the diverted water. It is questionable whether canal seepage losses are actual losses, because of return flow; recovery of such water for reuse is never complete, however, and in many instances it carries a considerably heavier salt burden than the water being transported.

SEPARATION OF SALINE WATER FROM FRESHWATER FLOWS

Increases in salt concentration can be avoided by denying entry of saline flows (natural or from irrigation) to the river or by desalinizing before allowing such waters to enter the river. Either solution requires interception. Complete interception is virtually impossible because of the percolation of water to and through deep strata, but conceivably at least the effluents from artificial drains can be collected. A precondition is to maximize irrigation efficiency, so as to minimize the volume of saline water to be collected per unit of salt. Desalinization, while technically feasible, involves major problems of brine disposal and - at this time - continues to be too expensive for irrigation or other low value per unit water application uses. (Table III-22.)

Salt Sinks

Lagoons can be created or natural sinks such as the Salton Sea in southern California can be utilized to confine the salt in collected waters. Within the lagoon, or sink, solar energy removes water from the brine. The end result is an accumulation of dry salts that might themselves have economic value, or certain elements might be extracted from the brines from certain areas during the drying process.

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[14] *"Research-Engineering Methods and Materials," Bureau of Reclamation Research Report, U. S. Department of the Interior, 1963, pp. 1-137.*

TABLE III-22

COSTS ASSOCIATED WITH EXISTING DESALINIZATION PROCESSES

Project	Method	Status	Size (Million Gallons/ Day)	Cost/ 1,000 Gallons
MWD of Southern California	Distillation	proposed	150	$0.22
San Diego	Distillation	under construction	1.2	$1.00
Israel	Distillation	under study	100	$0.29
Pilot Study	Ion Exchange	experimental	-	$0.40-1.00
Pilot Study	Reverse Osmosis	experimental	-	$0.25

Source: Compiled from Resources for the Future, and Office of Saline Water Reports.

Desalination

This process also could be combined with the salt sink concept. The end result could then be the salvage of a portion of the water as freshwater, in addition to the accumulation of quantities of dry salt.

Collecting Basins

These are used as temporary storage lagoons to concentrate saline waters. The brine, concentrated by evaporation from pond water, might be discharged during periods of peak flows.

Discharge Channels

Channels separate from the river might be constructed to transport highly salinized return flows to the ocean. An example of such a channel is the San Joaquin Master Drain that has been approved for the San Joaquin Valley in California.[15]

REDUCING EVAPOTRANSPIRATION

Obviously, the most complete and effective reduction in salinity induced by the evapotranspiration process can be accomplished by reducing the number of acres irrigated. Limitation of salinity increases can be most effectively promoted by curtailing irrigation in areas where salinity is a problem. Obviously the very mechanics of irrigation impose a self-regulating limitation on the extension of irrigation. A parcel of water can be effectively reused only so many times, the degree of recycling depending in large measure on initial TDS concentration. At a certain level of use intensity, it must have become too salty for additional application. Thus, either the quantity or the quality of a stream can become the critical limiting factor in irrigation extension. It is this phenomenon that leads to the growing desire for large scale interbasin water transfers.

But there are other possibilities less radical than reducing irrigation to reduce evapotranspiration by altering soil, water, and crop management practices. In particular, application of systems engineering to the irrigated agriculture of entire drainage basins should establish the trade-offs between water use agricultural procedures that result in optimum water use/agricultural production balances. Selection of crops, timing of growth, careful use of water, use of proper draining and transmission precautions, determination of desired water uses, even desalination - there is a great variety of elements to be balanced, a great number of remedies to be applied before it is necessary to resort to extensive irrigation restriction or large scale water transfers.

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[15] *Huffman, Elmo W., "Wastewater Disposal: San Joaquin Valley, California", Journal of Irrigation and Drainage Division, Proc. ASCE, 92 (IR-2), 1966, pp. 47-60.*

COST ESTIMATES FOR REMEDIAL OR CONTROL MEASURES

Costs of control measures for water quality related to irrigation depend upon the degree of improvement required and are determined by physical factors in individual drainage basins. It should be recognized that the basic remedy for degradation of surface waters by salinity involves reducing, diluting, or eliminating saline return flows into surface waters that serve as water sources for other users. The cost for alternative disposal methods will vary greatly among specific projects. Many of the possible remedial measures are not sufficiently developed to be immediately applicable, and still others involve market analysis beyond the scope of this report.

OIL POLLUTION

Spills of oil and other hazardous materials constitute a major pollution threat to the water resources of the nation. Both water and land-based facilities are sources of this danger to our streams and rivers. Each source, large or small, occasional or continuous, must be taken into account.

THE PROBLEM

Much damage has already been done from accidental or indiscriminate spillage of crude oil, petroleum and its by-products. Such spills have contaminated water supplies, killed fish and wildlife, created fire hazards, and destroyed or reduced the usage of recreational areas.

Waterborne Sources

World-wide waterborne casualties dropped .2%, from 2,408 in 1966 to 2,353 in 1967. (Table III-23.) Collisions were up, however, 18% from 922 to 1,090 in this same period.

The Torrey Canyon disaster is still fresh in many people's memories. This vessel was carrying 119,000 tons of fuel oil when she grounded off the Cornish coast of England in 1967.

There has been a steady progression in tanker capacity since World War II. The T-2 tanker of World War II carried 16,000 tons of fuel oil. In 1965 the average tanker had a capacity of 27,000 tons. New tankers delivered in 1966 averaged about 76,000 tons. Tankers now on order include 60 that will exceed 150,000 tons, and some will reach over 300,000 tons. Feasibility studies indicate tankers of 500,000-ton-capacity may be built in the future. As the size of vessels increases, it is obvious that the magnitude of disaster-potential due to accident also increases.

Foreign tankers or tankers under foreign registry are carrying an increasing amount of U. S. oil. Foreign ships carried about 20% of U. S. imports in 1945, 50% in 1951, and about 95% in 1964. Aspects of tanker pollution which are readily manageable under U. S. law may not be applicable to foreign vessels.

Commerce in potential pollutants is quite active on the 25,000-mile network of U. S. inland waterways. An estimated 188 million tons of petroleum products and hazardous substances were moved on these waterways in 1964. The inland fleet involves smaller vessels but they use confined water areas where spills spread quickly and endanger shore facilities and potable water supplies.

TABLE III-23

WORLDWIDE WATERBORNE CASUALTIES, U. S. VESSELS, 1966-1967

	FY 1966	FY 1967
Number of Casualties	2,408	2,353
Vessels over 1,000 tons	1,310	1,343
Tank Ships and Tank Barges	470	499
Locations:		
U. S. Waters	1,685	1,569
Elsewhere	723	784
Total	2,408	2,353
Types of Casualties:		
Collisions	922	1,090
Explosions	175	168
Groundings with Damages	302	282
Flounderings, Capsizings, Floodings	315	230
Total	1,714	1,770

Source: "Oil Pollution," report to the President by the Secretary of the Interior and the Secretary of Transportation.

Gasoline Service Stations

About 350 million gallons of used motor oil must be disposed of annually by more than 210,000 service stations operating in the U. S. The stations were once the key suppliers for used oils sent to re-refiners. In the past five years, however, reuse of oil has become an increasingly marginal business, due to changes in labeling requirements and tax laws. As the demand for used oil has diminished, the oil has had to be disposed in other ways, often by flushing into sewers.

Tank Cleaning Facilities

Most large shipyards have tank-cleaning facilities, but not all have the equipment to treat oily wastes.

Oily Waste Industries

According to the Bureau of the Census, over 10,000 industrial plants are major water users. Many of these plants have significant quantities of oil in their wastes. Untreated or inadequately treated wastes from such sources cause a continuing oil pollution problem in receiving waters.

Industrial Transfer and Storage

The United States has an extensive system of navigable internal water commerce routes as well as coastal sea lanes. Extensive coastal and riverside terminal facilities, now numbering about 6,000, have been developed for the transfer of commodities between water and land. Products arriving at, or departing from, these waterside facilities may be handled several times. Fragmentary information indicates that ruptured tanks, levee and dike failures, pipeline breaks and human failures are leading causes of spills. Retention levees around storage tanks are generally designed only for safety and fire prevention, not pollution control.

Pipelines

About 200,000 miles of pipelines, criss-crossing the United States, carried more than one billion tons of oil and other hazardous substances in 1965. Many sections of this network cross navigable waterways and reservoir systems, and the lines are heavily concentrated in populous areas where the demand for petroleum is great. This system exposes our watercourses, port areas, and critical drinking water supply areas to oil pollution. There are many spills, accidental punctures, cracked welds, and leaks from corrosion which require alertness and technical improvement.

Offshore Mining

Offshore oil and gas operations are being conducted in the Gulf of Mexico, the Southern California coastal waters, Cook Inlet in Alaska, and areas of the Great Lakes and the East Coast. These operations are a pollution threat due to potential blowouts of wells, dumping of oil-based drilling muds and oil-soaked cuttings, and losses of oil in production, storage, and transport. Pipelines laid across the ocean floor from the offshore platforms to on-shore storage facilities also pose a pollution threat. These lines are subjected to severe stresses by storms, and may be ruptured by dragging ships' anchors.

The Gulf of Mexico is perhaps the best illustrative example of offshore drilling operations. Since 1960 about 6,000 wells have been sunk in the Gulf. Many of the structures have been damaged or destroyed by hurricanes. The industry is compelled to remove damaged structures, but in many instances it is difficult to locate all the debris, and the larger pieces become a menace to surface navigation. As a result, shipwrecks, portions of storm-ranged structures, and other litter exist in profusion on the Gulf's continental shelf. The increased hazard of marine casualty has correspondingly increased the threat of pollution in these waters.

TREATING THE PROBLEM

We know the potential causes of oil pollutants; we have no estimate of the magnitude of pollution from these sources. Presently, there is little or no basis for cost estimates to control oil pollution. Recommendations for controlling oil pollution therefore cannot be accompanied with relevant costs.

A considerable amount of oil pollution can be controlled or reduced by reorganizing the standards and practices of the industry affected. For example, vessels can be built with smaller, stronger compartments in order to reduce the volume of oil spilled if collisions occur. Regulations should be developed on such factors as maximum speeds in critical areas, the maintenance and employment of radars, and ship control by automatic pilot in crowded or confined waters. Port safety advisory information should be available to all vessels entering U. S. ports. The Captains of the Port maintain current information concerning location and availability of berths, anchorage, navigational hazards, traffic conditions (such as major movements in progress), harbor sanitation rules and facilities, and other features of port activity which have a bearing upon safety and pollution control. Contact with the Captain of the Port should be mandatory for all vessels entering port.

More positive controls of the movements of hazardous cargo are necessary. First, it is necessary to recommend expanded use of well-defined shipping lanes. This would be a major step toward reducing the risk of collisions. Background in this field is already available in the use of approaches to New York and Delaware Bay, and in the area of drilling platforms in the Gulf of Mexico. Secondly, research is needed on the feasibility of a shore-based guidance system to promote safe movement of shipping.

Municipal sewage systems are able to cope with only limited quantities of waste oil. It is necessary either to expand these systems' facilities or to reduce or eliminate the amount of waste oil entering municipal sewage plants.

Shipyards with tank cleaning facilities should be required to have either an oil treatment installation or access to such an installation.

Oily-waste producing industries pose a more difficult problem because they are so numerous. However, some sort of collection system might well be initiated, with holding tanks to be emptied daily or weekly and taken to a central re-refining area.

Regarding industrial transfer, storage and pipelines, some of the most beneficial results would be obtained in expanding the training programs of personnel involved in this type of work. Designs of retention levees and materials handling requirements should include provisions for pollution as well as safety and fire prevention.

Care should be taken in laying pipelines to avoid critical drinking water supply areas, watercourses, and port areas. Where it is necessary to extend pipelines in such areas, extra precautionary measures should be initiated. These would include continuing surveillance of the lines, better material specifications, corrosion control methods, and higher welding standards. Automatic shutdown of pumps could be used in the event of pressure drops in the lines. Block valves could be installed at critical river crossings to minimize drain-back should a break occur within the river segments.

It is also necessary to strengthen mining platforms in the Gulf of Mexico to enable them to withstand violent storms. A marking device setting forth the locations of pipelines across the ocean floor would be desirable. Establishment of fairways is necessary. The situation appears to require both improved coordination among agencies which have responsibility for offshore installations, and the inclusion of effective pollution control provisions in mineral leases.

Controlling oil pollution will be a monumental task during the next few years. We have the technology but few of the facilities to measure the amount of pollution by type of polluter. Presently, there is technology to correct some types of oil pollution, but physical facilities are lacking. It will take time and considerable research and education to incorporate these controls in the economy.

CONCLUSION

In contrast to pollution caused by municipal and industrial wastes, that resulting from "other effluents" is unfixed and unspecific. Some pollution control measures and their costs can be roughly defined for certain types of pollutants. For others, there are no data available.

The fundamental difficulty in developing control measures for "other effluents" is that, until recently, the necessity or opportunity for such controls was relatively unrecognized. Very little effort has been made to quantify the pollutional effects, remedies, and control costs associated with such problems.

Some types of pollution cannot be controlled with present technology; for other types of pollution, controls are available but at considerable cost. Where no other feasible controls are presently available, stringent use regulations must be applied.

The "other effluent" area has no common denominator such as reduction in BOD loads in the municipal sector. Each type of waste may have a distinct method of control; possibly none are interchangeable.

Finally, any attempt to forecast a five-year remedial program for "other effluents" other than in terms of necessary research is difficult, if not impossible, at this time. Currently, it is necessary to make the best judgment possible with the technology at hand and to apply the results of available research. Where a pollutant is particularly harmful, and no control technology is available, it may be necessary to curb this particular activity.

APPENDIX I

BIBLIOGRAPHY

Atomic Energy Commission. Bonneville Power Administration; the Portland General Electric Co. and the Washington Water Power Co. Reviews, Reports and Discussions.

Bernstein, Leon. "Reuse of Agricultural Wastewaters for Irrigation in Relation to the Salt Tolerance of Crops." Proceedings, Symposium on Agricultural Wastewaters, Report No. 10. Water Resources Center. University of California. 1966.

Bullard, W. E. "National Program for Prevention and Control of Pollution From Mine Drainage." Unpublished Manuscript. April 14, 1967.

Clark, F. W. The Composition of Rivers and Waters of the United States. USGS Professional Paper 135. 1924.

Daly, R. F. and A. C. Egbert. A Look Ahead for Food and Agriculture. USDA. ERS. ERS-277. Washington, D. C. February 1966.

DeGreer, Myron W. "Chlorides Control - Arkansas - Red Basins." Meeting of the American Society of Civil Engineers and International Committee on Irrigation, Drainage, and Flood Control. El Paso, Texas. December 2, 1964.

Eliassen, Rolf. "Saline Water Conversion." Journal American Water Works Association. October 1966.

Evans, R. K. "Nuclear Power Reactors." (A Special Report.) Reprinted from Power. March 1965.

Garstka, Walter U. "Evaporation and Its Reduction." Proceedings International Seminar on Soil and Water Utilization. South Dakota State College. Brookings, South Dakota. July 1962.

House Committee Print No. 18. Acid Mine Drainage. U. S. Government Printing Office. Washington, D. C. April 19, 1962.

Howard, C. A. "Irrigation Runoff." Journal American Water Works Association. November 1953.

Huffman, Elmo W. "Wastewater Disposal: San Joaquin Valley, California." Journal of Irrigation and Drainage. Division Proceedings. ASCE. 92 (IR-2.) 1966.

Lammering, M. W. Uranium Milling Industry; Nuclear Electrical Power Industry. (Drafts, reports in mimeograph, Technical Advisory and Investigations Branch, Division of Technical Services, FWPCA.)

McNeal, B. L. and C. A. Bower. "Evaporates in Soils." Water of Rocks and Minerals in Soil Genesis, Chapter 8. Volume 1 of the Encyclopedia of Soil Science.

Myers, L. E. "Water Harvesting." Presented at the 17th Nevada Water Conference. Carson City, Nevada. 1962.

National Academy of Sciences, National Research Council. Waste Management and Control. Publication 1400. Washington, D. C. 1966.

Presidents Science Advisory Committee, The White House. Restoring The Quality of Our Environment. Report of the Environmental Pollution Panel. November 1965.

A Report to the President by the Secretary of the Interior. A Survey of Strip and Surface Mining in the United States. (Draft-Impact p. 20.)

Robinson, T. W. "The Phreatophyte Problem." In Symposium on Phreatophytes. Pacific Southwest Interagency Committee. 1958.

Secretary of the Interior and the Secretary of Transportation. Oil Pollution. A Report to the President. Unpublished Report dated January 1968.

Traylor, Duane. "Cattle Feedlot Pollution." Unpublished Manuscript. U. S. Department of the Interior, Federal Water Pollution Control Administration. 1966.

Tsivoglou, E. C. and W. W. Towne. "Sources of Radioactive Water Pollutants." Reprinted from Sewage and Industrial Wastes. February 1957.

U. S. Department of Agriculture. (Especially the in-house reports from the Soil Conservation Service and the Agricultural Research Service.) November 1967.

U. S. Department of Agriculture. Irrigation of Agricultural Lands. Monograph No. 11. 1967. Pages 45-46.

________. Basic Statistics of the National Inventory of Soil and Water Conservation Needs. Statistical Bulletin No. 317. 1962.

________. U. S. Census of Agriculture. 1959 and 1964.

U. S. Department of the Interior, Geological Survey. Water Resources of the Upper Colorado River Basin. Professional Paper 441.

________. *Quality of Water: Colorado River Basin*. Progress Report No. 3. (FWPCA records on open file.) January 1967.

________. *Surface Mining and Our Environment*. 1967.

________. *Wastes From Watercraft*. Senate Document No. 48. Federal Water Pollution Control Administration. August 31, 1967.

________. "Research-Engineering Methods and Materials." Bureau of Reclamation Research Report. 1963. Pages 1-137.

________. *Handbook of Pollution Control Costs in Mine Drainage Management*. Federal Water Pollution Control Administration. December 1966.

Wadleigh, C. H. "Wastes in Relation to Agriculture." U. S. Department of Agriculture. Agricultural Research Service. Unpublished Manuscript. April 1967.

Walton, Graham. "Agricultural Wastewater - Treatment and Recycling for Agricultural Use." Technical Advisory and Investigating Activities. Technical Services Program. U. S. Department of Health, Education, and Welfare. Federal Water Pollution Control Administration. R. A. Taft Sanitary Engineering Center. Cincinnati, Ohio.

Willrich, Mason. "International Control for Civil Nuclear Power." *Bulletin of the Atomic Scientists*. March 1967.

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